High Capacity Optimised Rapid Transport (HCORT)

Designed by Ken Dawber
Email: KEN@JYPES.COM

Version 0.0.7

Date: 12th June 2017

http://HCORT.COM
http://HCORT.ORG

Table of Contents

Objectives:

This proposal seeks to outline a proposed new public transportation system which will do the following:

- drastically reduce the production of greenhouse gases and other pollution
- cut the time taken for people to get to and from their destination to less than a quarter of the current time taken
- reduce the road toll to a fraction of the current deaths and injuries
- get rid of the grid lock that is occurring on our roads
- reduce the energy used for transportation to a fraction of what is currently used

Compared to current schemes of creating new road freeways (expressways) or creating new rail lines, this proposal seeks to perform the above while

- costing far less than other alternatives
- getting rid of or minimising the confiscation and compensation of properties that the other alternatives tend to require

Introduction:

This new transportation system has been named 'HCORT' as it is a High Capacity Optimised Rapid Transport system.

HCORT is a set of principles, concepts and ideas that advance upon Personal Rapid Transit (PRT) concepts to create a complete design for a new transportation network. This new transportation system will replace trains, light rail, trams (streetcars), buses and most use of roads.

Personal Rapid Transit (PRT), called Podcars in Europe, is a controversial set of principles for transportation systems that can be summarised as follows:

Automated networks of small vehicles on express guideways

An expanded definition of PRT is given in 'USA's Official Position' in Appendix A.

Although HCORT advances the principles of PRT, it still assumes that the underlying principles of PRT are correct and that PRT takes us towards a more optimal transportation system. For this reason, the document below starts with a demonstration created by this author to show the advantages of PRT:

Ken Dawber's Demonstration Analysis of PRT's Advantages

The following is a demonstration of how the principles of Personal Rapid Transport (PRT) take transportation systems towards optimal.

Lets start with current transportation types such as 'Bus Rapid Transport' (BRT) or 'Light Rail'. With these transport types, good transport systems can have the following characteristics:

a) Vehicles run on a dedicated path that acts like a freeway (expressway) between stops.

b) For each stop, the vehicles determine if there is a passenger requesting that the vehicle stops, and only needs to stop for such requests. That is, if there is a passenger to pick up on the stop or if a passenger on the vehicle requests the vehicle to stop there.

When these characteristics are implemented, both of these transport types are superior to other types that don't offer it.

Now let us take a route in medium density and assume that the BRT or Light Rail ran every 10 minutes in some period.

When we look at vehicles on these transport systems we typically find them as large articulated vehicles.

What would happen if instead of going bigger, we went the other way and made them smaller.   Lets take each of the current large vehicles and split it into say 20 smaller mini people movers, but keep the same number of passengers on the system.

1. Now, when passengers wait at a stop, they would only wait for up to 30 seconds rather than up to 10 minutes.

2. With the low number of passengers embarking and disembarking the vehicles only rarely stop at any stop. Consequently, the passengers get to their destination in less than half the time.

3. The vehicles completes their route in less than half the time so it can go around the route more than twice in the time the larger vehicle would have gone around once. This means that we actually needed less than half of those 20 vehicles to transport the same passengers.

4. The rarity of the vehicles stopping mean that this system already uses less energy, and as a consequence, less damaging effects to the environment. Further changes to network to take it to PRT specifications, as specified below will make it that the energy used is substantially less than that of the original transport type.

Now there are obviously a few things that are not realistic with this.

1. When a vehicle stops at a stop it would hold up those behind. This needs to be fixed but the fact that these vehicles are very small allows the fix for this. We can now make smaller tracks for the vehicles. The freed up width can now be used to place sidings along the side for the stops, leaving the main route as a full freeway (expressway), not just a freeway between stops. The overall area used by the system is still less than the original system.

2. This is so good for the users that many people will stop using their cars and use this public transport system. As a consequence the figures would change drastically. In the case of public transport, this increase in use has to be treated as a further advantage as it primarily comes from a conversion from standard car use.

3. One is tempted to think that the 20 vehicles would cost more than the single large vehicle. Current costs are actually the opposite of that. This is gone over in Appendix B 'Size Matters'.

4. Up to recently, each of these vehicles needed drivers, which would make it uneconomic. In effect this demonstrates that the only advantage of the trend towards large articulated vehicles is to put drivers out of work.

   The overall trend of technology is to automate everything and we can expect that in time most public transport vehicles on dedicated paths will be driverless, whether massive in size or micro. With current costs of technology, once designed, the incremental costs of automating additional vehicles is minor.

While the above has taken us towards PRT, it is not yet fully PRT. Other changes needed to take this to the PRT specifications are as follows:

1. PRT changes the system methodology of passenger pickup. Instead of vehicles travelling around scheduled routes, vehicles are simple repositioned by a central computer to go the stop most likely needing it. The vehicles simply wait at stops until used there or repositioned by central control. For all times outside of peak, when a user goes to a substation, they will almost always find a vehicle waiting for them to take them on their journey. If a vehicle isn't there, the user requests one and the system will send one to that substation.

2. Travel is point-to-point anywhere in the network in the most direct route and without having to change vehicle. With other public transport, the user has to go out of their way to get interconnections to achieve travel to many destinations. For example, go into the city to get an interconnection to a route coming back out from the city, sometimes to a destination reasonably close to the origin. This becomes a lot more important when the network grows to cover the city.

3. PRT often recommends even smaller vehicles than the 20th of the large articulated vehicle in the above analysis. Optimal sizes in terms of minimisation of energy are normally calculated as being in 1 to 3 people per vehicle although most PRT designs are 2 to 6 people per vehicle. The extra size allows a family or group to stay together.

4. As dedicated guideways for smaller vehicles are cheaper than dedicated guideways for large vehicles, PRT principles recommend networks that are a lot denser than that seen with BRT, Light Rail or trains.

5. The automated network makes it easy to provide a network that is available for use 24 hours a day, 7 days a week.

6. To make BRT or Light Rail efficient in peak periods, most implementations keep each of the stops a long distance apart as compared to standard bus or tram stop distances. There is now no need for this. Stops can be very close together and the system runs just as efficiently.

The other aspect to PRT is how dedicated automated guideways allow very high throughput of traffic while costing only a fraction of alternatives. This is demonstrated in a later 'Throughput Calculations' section.

Background:

The background to this is the history of Personal Rapid Transit (PRT) [11]. Since the late 1960s there has been substantial research efforts on PRT with most of this being in the 1970s and 1980s. Most of the implementation attempts ended up as very expensive failures.

How much these failures were due to the concepts being wrong, the immaturity of the technology of the day, politics, the efforts of those organisations or people that would be negatively affected by this technology, poorly managed or engineered projects or just bad luck etc. are issues that remain hotly debated.

Much of what is included in the concepts herein is based on the authors research on the problems that occurred in these projects and is an attempt to circumvent or otherwise not make the same mistakes.

Regardless of these earlier expensive failures, along with the controversy on the concepts, there has recently been major research studies by, or on behalf of, the transport authorities of both the USA and Europe. As a consequence of these studies, it can be stated that the position of transport authorities in both the USA and Europe is that we should be directing research towards implementing PRT/ATN/podcars. Automatic Transit Networks (ATN) is another name for PRT that is being used in the USA.

Details on the findings of these studies, including a description of the main PRT/ATN/podcar concepts, is included in Appendix 1

Notes:

High Capacity PRT (HCPRT) network designs are herein defined as designs suitable as primary transportation networks for a large city.

While there are a small number of PRT systems [11] that have been implemented, none can be called High Capacity PRT and it is doubtful if any of the implemented designs would be suitable for taking the majority of a large city's traffic as this HCORT system is designed for.

A PRT vehicle in Masdar City, a planned city in Abu Dhabi, in the United Arab Emirates

While the HCORT network described herein is a full and specific transportation system, each of the individual principles, concepts and ideas expressed herein is able to be used in other PRT/ATN/podcar networks and similar (such as Group Rapid Transport).

One of the reasons for creating this document and getting it published was to assure that the many ideas within it are published and are therefore in the public domain.

The Central Principles of Ken Dawber's HCORT Design

The Central Principles of Ken Dawber's HCORT Design are as follows:

- The overall system design must be open source, open design and in the public domain in terms of all guideway definitions. Specifically, the guideway design itself, all interface definitions and the design of any component required by vehicles must be in the public domain.

- Should include latched platooning on the main HCORT freeways (expressways). When vehicles platoon, the vehicles approach each other while travelling at or near the full speed of the freeway and gently touch on large bumpers and latch together. i.e. clamp, clasp, attach or otherwise fasten together. The electronically controlled latch can be controlled by either vehicle. Reasons for adding this latch are as follows:

    - We currently have a history of major projects that failed due to or related to platooning without latches. These problems included:
        - Authorities not accepting the concept of non latched platooning (i.e. groups of vehicles travelling close together) as a safe way to travel.
        - Problems getting non latched platooning to work reliably and the vehicles bumping into each other.
    - We have a history of good safety with having vehicles latched together as trains or trailers. Therefore, with only a very small period of time when any distance between vehicles exists, the overall journey will be safer than having distance between vehicles throughout the journey.

- Vehicles must be based on four wheels with rubber tyres. These will probably be pneumatic although there are other alternatives. Reasons for rubber tyres are:

    - Allows Dual Mode. That is, allows vehicles to also run on normal roads.
    - Ability to use standard car technology for suspension, wheels, brakes, steering, shock absorbers etc.
    - Reduces Intellectual Property problems. Cities don't want to run on a road or rail system where some private company owns rights to it.
    - Vehicles able to stop (brake) and start (accelerate) quickly
    - Quiet
    - Good ability to handle steep grades
    - Vastly superior cost per capabilities.
    - Large range of vehicles already developed.

- Must allow specially designed vehicles to utilise the system where the vehicle also has the ability to drive on normal roads. i.e. Dual mode vehicles.

- ► Initially, projects creating or designing HCORT systems should not design or create any vehicles in total for the system. Rather, the design or creation should be that of kits that allow modification of standard electric cars. Reasons for this are as follows:

  - Electric car technology is advancing too quickly for systems designed for large networks to keep up with. Large new networks like these will have a slow implementation or uptake.
  - There is a large range of types of HCORT vehicles needed, both those described herein and others, and a generalised kit will be needed to allow all of these to be created.
  - Cars originally designed for roads are a lot more sophisticated than specifically built vehicles, particularly in terms of safety features that the HCORT system should utilise. For example, cars are generally built with anti-locking brakes, stability controls and air bags and all of these would be used by the HCORT passenger vehicles.
  - Designing specific vehicles are generally attempts to lock in the manufacturer as always being the supplier. This will limit the usefulness of the system.

  Note: Once a major implementation occurs there will be a substantial number of vehicles purchased. With this purchasing power, there will be a large number of further modifications implemented such as taking away the steering wheel and other controls etc., adding an emergency exit, particularly to the front of the vehicle.

- ► Solid bumper bars with latching should be developed as part of the kit used to convert electric cars to HCORT vehicles. These are currently envisaged as being like 1980s style Volvo bumper bars. The bumper bars will include shock absorbers (i.e. damping which insures that there is little spring rebound). Many of the various sensors will be incorporated in the bumper bars. Use of these bumper bars is expected to aid in independent modular component design as it allows a design which includes mechanical aspects to be created as one larger module incorporating a number of the smaller modules used to make the vehicle design. It could be designed with lightweight Fibre-reinforced plastic (FRP). These bumper bars must produce a standard height above ground level where vehicles will meet each in any push and shove and where sensors or reflectors etc. are mounted.

- ► The system should utilise the previous roads as a 'near grade' system through out most of the outer suburbs. This is particularly so for the branches to sidings that contain the substations as these are best placed on back streets substantially reducing implementation costs. The HCORT freeways in most outer suburbs will run down the centre of what was previously minor arterial or distributor roads. When these roads intersect with standard roads the HCORT lanes will sink into the ground, like an open ditch, with a bridge over the HCORT lane for the standard road traffic. Note that this is only 'most' of the time. It is expected that there will be many streets where the use of any part of the street will cause excessive disruption to the road traffic or for various other reasons will not be possible. In most of these other cases the new network will be implemented as elevated guideways, although it can also be implemented as tunnels.

- ► All vehicles must be severely height limited. Reason for this is as follows:

  - This is needed in order to allow easy implementation of the 'near grade' sections.

- ► Substations serve a similar purpose to bus stops or taxi stands (taxi ranks). Rather than having substations along the HCORT freeways, most substations are on side branches (sidings or spurs), with these sidings typically at a right angle to the HCORT freeway, with many substations some distance away from the HCORT freeways. Reasons for this are as follows:
    - This substantially increasing the percentage of the population that the system services.
    - Due to the fact that multiple substations on a siding can now share acceleration/deceleration lanes the cost per substation is decreased.
    - Makes it easier to fit the HCORT freeways into existing roads while still providing access to properties on those roads.

- ► The system uses multiple types of guideway. These guideway types are as follows:
    - Main HCORT freeways (expressways) over longer distances.
    - Deceleration and acceleration lanes next to the main HCORT freeways. These are short sections, sufficient in length for the speed change plus some buffering of vehicle position to allow the vehicles to merge into the stream of traffic they are entering.
    - Turn lanes. These are often connected to the main freeways through deceleration and acceleration lanes.
    - Sidings. In residential areas, each of these typically connects a small group of substations to one or more HCORT freeway(s) via their deceleration and acceleration lane(s). With smaller substations, the substation bays are directly accessed from the siding. It also provides access to the side lanes. A particular type of siding lane is the substation manoeuvring lane that occurs in larger substations.
    - Side lanes which allow HCORT vehicles to directly enter properties. These side lanes also allow normal road vehicles to enter properties. The normal vehicles must use a mobile app or electronic device for their control. This effectively provides time multiplexing so that HCORT vehicles are not on the lane or in the entrance to the property at the same time as normal vehicles. Properties will often need their kerb ramp (also called curb cut, curb ramp or dropped kerb) extended in order to make the sharp turn entering or leaving their property.

- ► The use of near grade for sidings and side lanes requires a large number of near grade crossings. With most of these the HCORT lanes will sink into the ground, like an open ditch, with a bridge over the HCORT lane for standard road traffic. The number and placement of these will depend on the street pattern but one of the most common places they will be needed is close to the end of the sidings where the sidings connect to deceleration or acceleration lanes. Typically this will be close to a sharp 90 degree turn. In this case the crossing needed for road traffic is only a single one way lane of road traffic plus space for pedestrians and bikes in both directions. Only one thin HCORT lane has to be crossed over.

- ► The system must extend out beyond the outer suburbs. Reasons for this include:
    - Needed to purchase land cheaply for HCORT vehicle night parking space.
    - Land purchased would also be used for vehicle maintenance.
    - Land purchased would also be used to provide parking to properties that had lost their street parking.
    - Land purchased would also be used to provide parking to users that were not within walking distance.

- ► A range of different vehicles is designed for use with the system. These have the same width and maximum height but can be different lengths. Some of these vehicle types are purely designed for carriage of goods or special purposes.

- ► At least two types of automated driverless vehicle are available at substations. If the particular vehicle type that a passenger wants is not at the substation, then the user can request it from a console. Details of these two types are as follows:

  - Transit microbuses are around the size of small cars. They are designed for shared transport but only allow a small number of passengers and only provide simple seating. They do not provide for any significant luggage. Even parents with prams are unable to use them. Other than peak periods, most substations would have several microbuses waiting for passengers. The waiting microbuses are pre-destined to a range of destinations. For example, a suburban substation might have a microbus pre-destined to head towards the city and another pre-destined to head away from the city. Typically they pick up all their passengers for their current journey from just one substation. Each passenger tells the microbus which substation they wish to go to and the microbus only stops at those substations.

  - Podcars (also called 'Personal Rapid Transits' or PRT) allow a user to travel in a single hop to any substation through out the new system. They only have one or two seats. They allow carriage of considerable luggage including bikes or prams and can be used by people with walking frames, wheel chair users and users of disability scooters. An enhanced shopping trolley is also designed for their use. The provision of podcars provides better transportation service to otherwise excluded people compared to that of the microbus system. This along with appropriate subsidies, allows the system and the state to fulfill its obligations.

- ► The vehicles are electric vehicles powered by battery. Power for charging the battery is provided at various places along the HCORT freeways and while parked at parking bays. More details on this are provided in the section entitled 'Vehicle Design: Power'

- ► The overall speeds of the system, particularly the speed of vehicles on the main HCORT freeways (expressways) are faster than those normally seen on metropolitan transport. Higher speeds have the following advantages:
  - Allows passengers to get to their destination quickly.
  - Reduces wait time for vehicles.
  - Reduces the number of vehicles needed for the system to transport a given throughput.

  Speeds envisaged for the system are as follows:
  - 160 km/hr on HCORT freeways (i.e. 100 mph)
  - 40 km/hr in 90 degree turn from HCORT freeway to HCORT freeway (with 10% bank)
  - 20 km/hr in 90 degree turn from HCORT freeway to siding (with 10% bank)
  - 80 km/hr on sidings where fenced
  - 20 km/hr on sidings where unfenced
  - 10 or 20 km/hr on siding side lanes

The current Tesla Model S electric car with a maximum speed of 249km/hr is an example of current electric car technology where the technology of our road system hasn't kept up with the technology of the vehicles that travel down it.

- Users are able to implement virtual trailers or virtual trains, where the users control multiple carriages throughout a journey. Examples of this are:

  - A user can order a goods carriage to carry goods then have a separate carriage to carry themselves.
  - A school teacher can control multiple carriages carrying their students.
  - Where the height of a disabled person on an electric mobility scooter is too tall to allow them to ride on the scooter while the scooter is in a new HCORT vehicle, then the disabled person can ride in one carriage while the scooter is carried in a separate goods carriage.
  - Tradespeople, lawn mowing services and gardens services etc., can have multiple carriages carrying their tools and bring in further vehicles for the disposal of waste.
  - Police can implement police vans (i.e. paddy wagons) for carriage of prisoners separate from the vehicle that the police travel in.
  - Specially designed fire engine vehicles are likely to require multiple vehicles.
  - Specially designed ambulances are likely to only have room for one ambulance officer/paramedic with the person on the stretcher. Further ambulance officers/paramedics would travel in a more standard vehicle.

- When the virtual train concept is implemented to carry more people or to carry animals, there will be the availability of audio visual systems between carriages that allow audio visual conversations between passengers in different vehicles within the train. These will be of a high standard to provide a significant virtual presence of those passengers physically in other carriages. The operation and control of this would have several modes so that there were options to make it suitable for teachers with young students, parents with children or groups of people travelling together.

- Each vehicle designed for carriage of people will have a number of video cameras and microphones. The central control will have substantial video surveillance capability. Computers will be used to evaluate the audio video data to locate data that it recommends the central control people to review. For more information on this see the section entitled 'Rape Wagon'.

- The track surface will be guaranteed free of bumps to a degree that allows vehicles to be lowered, compared to vehicles on ordinary roads. Dual-mode vehicles can use height adjustable suspension [18] to lower the ride height or ground clearance as they enter the HCORT system.

- U turn lanes are provided at either end of the HCORT freeways so that the two lanes (one in each direction) combine to create an infinite loop. Y intersections and offshoot freeways can be slightly different in the implementation of the infinite loop. The infinite loop can be implemented to incorporate all the branches within a single infinite loop.

- When HCORT freeways are at or near ground level or otherwise able to be accessed, they are fenced off. The fences will also enclose the acceleration and deceleration lanes. These fences will be substantive protection. That is, even if individuals decide to try to intrude into the guideway, the fences will make it beyond most people's capability.

- Sidings may also be fenced off or be fenced off for part of their length. The fences may be substantive protection similar to those for HCORT freeways or relatively minor. The allowed vehicle speed allocated to that part of the siding will be related to the safety of that speed which will be mainly determined by the guideway fencing.

- For properties which have lost parking or otherwise without full access to a traditional road, the system will offer free or cheap parking at large parking stations. These parking stations have full access to the traditional road system as well as to the new system.

- All HCORT vehicles must be able to operate in reverse. They must be able to do this in all guideways and in the case of HCORT freeways, they must be able to this at a substantive speed in order to be able to clear a freeway after an accident. More details of this is given in a section entitled 'Operation in Reverse'

- ► The guideway system should primarily be treated as an alternative to adding extra road throughput such as an alternative to adding a road freeway (expressway) rather than as a way of adding an extra public transport network like a railway. Its costing should primarily be compared to that of adding extra capacity to the current road network with the public transport vehicles being considered in a similar manner to that of buses over the top of roads. Implementation of guideways should be done by the authorities creating new road transport. Reasons for this include the following:
  - Some vehicles are dual mode, able to go on both normal roads and on this HCORT system. In time, these may be a major part of the traffic.
  - Some parts of the system such as side lanes continue to be parts of the road system as well as part of this new HCORT system.
  - The vehicles used within the system are the same or close to vehicles used on roads and have the same limitations and requirements such as headways etc.
  - Overall the system becomes a full network in the same way as the roads are a network, which is distinctly different to the route system of trains and trams etc.
  - This transportation system is expected to be able to shift a very high percentage of current road users to using it whereas traditional public transport systems such as buses can only shift a small proportion of road users onto their use.

- ► All states and countries that will implement an HCORT system or similar will benefit from international standards and/or agreements that specify details of guideways, vehicles, interfaces and communication protocols.

- ► Initial design, development and test is best performed as a cooperative effort across a large number of states and countries. More information on this is provided in a section entitled "Cooperative Design".

- ► Base the design on technologies that are proven as currently economically optimal or near optimal. While there are many technologies that show great promise for the future the addition of each such technology adds risk to this project. The size of the advantages that the base HCORT design provides, justifies getting it done with the least additional risk. This doesn't mean that these other technologies shouldn't be worked on as alternative implementations, but the system should be initially designed tested and implemented without them. Other technologies can then be implemented into specific guideways, preferable in such a way that vehicles designed for the new technologies are also able to work on the initial implementation. Promising technologies of the future that are not yet economically proven include magnetic levitation, ground effect vehicles, linear motors, evacuated tube and roadway magnetic resonant coupling.

Alternative Description and Details of HCORT.

HCORT is a fully automated rapid transport network suitable for cities, towns and their interconnections which is extremely cheap to implement and run. All vehicles are automated driverless vehicles that run on pneumatic tyres on a near standard road surface.

The assumption is that all vehicles in this new transportation system are electric vehicles and sometimes utilise two trolley poles for power. They all have some storage of power so can go some distance without the power lines.

It could alternatively be implemented with standard combustion engine vehicles or allowing a combination of both electric and combustion engine vehicles but the proposal herein is electric.

A road that was previously a minor arterial or distributor road is converted to a new single lane each way HCORT freeway (expressway) system. Alternatively, a pair of minor arterial roads, possible several blocks apart, are converted to one way single lane HCORT freeways with each being in opposite directions, the pair together acting as a two way system. Either way, full speed U turn lanes are provided at either end of the HCORT freeway so that the two lanes combine to create an infinite loop.

Vehicles on this HCORT freeway system are arranged in platoons of vehicles where groups of automated driverless vehicles with large bumper bars are able to travel at very high freeway speeds with each touching the adjacent vehicle(s). Consequently, a single lane each way HCORT freeway system is able to handle more traffic than an ordinary ten lane road freeway/expressway.

The freeways have embedded within them electronic guideways. The vehicles simultaneously use multiple guideway technologies. The area taken up by the HCORT freeway lanes is a lot less than normal roadway lanes as the vehicles are precisely positioned within the width of the laneway and the maximum width of vehicles is small. The HCORT freeways are separated from the remaining area of the roadway by fences.

All vehicles on the new system have a low maximum height. At each overpass (flyovers or grade separation) the new HCORT freeways can be dug down. Beside the new HCORT freeway, the new system can provide a walkway and bikeway boulevard that the overpasses must pass over.

The characteristics of this new HCORT freeway system is designed so that it can be implemented through out a city on what was previously minor arterial or distributor roads with little need for purchase of properties or compensation of the residents or businesses residing alongside it. Use of space from major arterials, highways and expressways would be rare so the original transportation system is little hindered. While many overpasses have to be created, they are of low cost due to the low or no ramps, low span size, low pier height, high numbers to be manufactured, ease of manufacturing offsite and lack of ability for traffic to turn at these overpasses.

It is also possible for these high speed HCORT freeways to be implemented on elevated flyovers. The above 'near grade' design allows residents to drive their traditional vehicle into and out of their properties but destroys the road's ability to handle through traffic and stops most of the parking on the side of the road. Where this near grade would be implemented, the increase in transport provided by the system far outweighs the loss of traffic. Where the loss of through traffic was considered important, elevated flyovers can be created that allow full traffic flow underneath. Elevated flyovers can also be used to cross over areas where there are no current roads such as crossing over parks etc and can be used to provide turns such as the frequent U turns that the system needs.

Either near grade or elevated, it is possible for the HCORT freeways to be multilane. In the case of a three lane system the middle lane can be used to enhance throughput in the direction most needed at any time. As the HCORT vehicles are generally not parked in the CBD, most of the time the traffic towards and from the CBD will tend to be symmetrical. The extra lane can also be used to provide a branch around while a malfunctioning vehicle is being removed.

On each side of this HCORT freeway are a number of sidings. These sidings are slow speed side branches down side streets. Typically, these sidings go around a block or two. Each siding typically services two to six substations.

At the substations two types of automated driverless vehicle are available. These types are podcars (also called 'Personal Rapid Transits' or PRT) and 'transit microbuses'. In normal use these podcars and microbuses don't have driver controls such as steering wheel, brake pedals or accelerator pedals.

Transit microbuses are around the size of small cars. They are designed for shared transport but only allow a small number of passengers and only provide simple seating. They do not provide for any significant luggage.   Even parents with prams would be unable to use them.

At any time other than peak periods, most substations would have several microbuses waiting for passengers. The waiting microbuses are pre-destined to a range of destinations. For example, a suburban substation might have a microbus pre-destined to head towards the city and another pre-destined to head away from the city. Typically they would pick up all their passengers for their current journey from just one substation. Each passenger tells the microbus which substation they wish to go to and the microbus only stops at those substations.

Podcars allow a user to travel in a single hop to any substation through out the new system.   They allow carriage of considerable luggage including bikes or prams and can be used by people with walking frames, wheel chair users and users of disability scooters. An enhanced shopping trolley is also designed for their use.

The provision of podcars provides better transportation service to otherwise excluded people compared to that of the microbus system. This along with appropriate subsidies, allows the system and the state to fulfill its obligations.

The substations have little infrastructure, more like bus stops than train stations. All the vehicles they service have low floors so there's no need for significant platforms. When users arrive, the vehicles they'll enter will more often be there, or within a short time of being there. Most users will be seated inside heated or air conditioned carriages while waiting so there is only minimal seating and shelter at substations.

The substations will have consoles for users to make requests.   If the type of vehicle, e.g. podcar, is not waiting, then the user can request it through a console. Similarly, if the user wants a microbus but their destination is different to the predestinations on the current waiting vehicles, the user can request it on a console.

A car running on the traditional road system enters the new system through automatic gates on a special entrance lane. Other than the large bumper bars back and front, the car looks like a relatively normal car with traditional pneumatic tyres but the car is an electric car. The new HCORT system senses the car and checks it out. Assuming the car passes the checks, the HCORT transportation system takes over automatic control cutting off the ability of the driver to control the steering, brakes and accelerator.

Under control of the HCORT transportation system, the car withdraws it's side view mirrors and extends its trolley poles that charge its batteries. If the car is a combined electric and internal combustion, the combustion engine would be turned off.   Under system control the car accelerates into the freeway and then gently pushes against the vehicle in front. A latch then latches the two cars together.

Even though some of these cars would be privately owned, the drivers are able to disembark at substations. The overall system would then be responsible for controlling this vehicle to appropriate parking and ensure that it is fully charged. Drivers are able to use an Internet web page or similar facility from which they can organise where they will meet up with their vehicle.

The HCORT freeways are fenced off and all crossings such as pedestrian crossings are at a different level. Along side of the HCORT freeway at various points along it are deceleration and acceleration lanes needed for the exits and entrances. These are enclosed within the same fences.

There are garden beds along side of the HCROT freeway at various places where deceleration and acceleration lanes are not needed. These areas have a hopefully rarely used alternative purpose. Malfunctioning vehicles can be pushed into these areas. This is one of the uses for the bumper bars.

There are automatic gates between the traditional streets and the various side streets being used for this new system. Residents who still drive traditional cars will have special electronic controls fitted to their vehicle.   As well as giving them a control to open the gate to their local area, it will output a signal that gives their vehicle's position.

The sidings may or may not be fenced, and even if fenced, the fences used are not the strong fences used for the HCORT freeways. As well as the sidings there are side lanes which the HCORT vehicles can travel on. When the podcars and microbuses travel on these side streets, particularly the unfenced ones, they do so at a slow speed. Residents are meant to cross side streets at provided lights or bridges but in some places there may be no barriers enforcing it.

The residents, who still can drive on these streets, are required to follow a set of special rules. These rules will in general mean that the automated vehicles have right of way. Regardless of whether these rules are followed precisely or not, there will be times when a resident's vehicle hinders the path of an automated vehicle. The automated vehicles have the following facilities for handling this.

1) The resident's vehicles output a signal providing their position. The automated vehicles use this as their primary means for collision avoidance.

2) Information from sensors at the front of the vehicles is combined with stored information providing normal expected sensor response for each position of the vehicle. Divergence from expected response is used to indicate possible obstacles.

3) Central System override control can be used for collision avoidance. This could be instigated by any of the following:

a) Sensors in the street have detected an intrusion into the path of the automated vehicles or
b) A user of an automated vehicle has pushed an emergency button or
c) A central system controller noticed a problem on their cameras.

The operation of the automated vehicles within the side streets is referred to as pseudo autonomous. In some respects it looks autonomous in that they appear to mix with ordinary resident traffic but in the early versions it is a long way from being fully autonomous. This system's automated vehicles are following hidden electronic guideways.

Fully autonomous would mean that the vehicles can be driven driverless in streets that haven't been modified for them. This is a very much safer alternative than autonomous.

As the currently experimental autonomous vehicle technology progresses sensors, algorithms and other parts of those systems may be incorporated into this new system, hopefully increasing this system's speed and safety in sidings and side lanes.

It's also possible for factories, warehouses, shopping centres, airports and other businesses to have a special goods entrance and exit to the new system. Goods would be carried in automated driverless vehicles designed for goods carriage (goodspods). The goods entrances and exits can be from and to the lane closest to the business as the system will have U turn facilities within it.

The height and weight limitations means that it is not possible to carry intermodal containers (i.e. shipping containers used for sea freight) but the various 'unit loads' currently being standardised through out the supply chain can be carried. Unit loads are standardised single "units" that can be moved easily with a pallet jack or forklift truck and are designed to pack tightly into warehouse racks, intermodal containers, trucks, and railway goods carriages. The system can also handle the majority, but not all, of the air cargo unit load devices (ULD). These are standard pallets or containers used to load luggage, freight, and mail on aircraft. Similarly, the system would handle various other standard pallets such as the Australia Standard Pallets so long as they were not stacked too high.

Substation users should have access to rubbish bins, preferably different rubbish bins for different rubbish types (recyclable etc). The system is able to have specially designed goodspods that are able to automatically empty these rubbish bins and take the rubbish to the appropriate depots.

Substations are the most convenient places to have post boxes allowing the postage of mail and parcels. The Post Office will be able to have automatic pick up of posted mail using specially designed goodspods.

Substations will also have a pick up and drop off for enhanced shopping trolleys. These trolleys are enhanced to allow large amounts of shopping to be carried over a larger distance than traditional shopping trolleys. Users of the system can use cards they use for fares (e.g. identity smart cards) to access the trolleys and the system senses when and to which substation each one has been returned. Users will have the ability to keep them at their residence overnight and return them to their nearest substation when they go to the substation the next morning on their way to work.

The system will have specially designed goodspods to automatically pick up excess shopping trolleys from typical drop off points and take them back to typical pick up points such as substations at supermarkets and shopping malls.

Substations may also have shared locked goods boxes. Specially designed goodspods are able to deliver goods into these boxes. When local residents or businesses order goods they provide information from their identity smart cards. When the box delivery goodspod delivers goods to a spare box, it provides that information to the lock on the box. The local resident or business is then able to access the goods at their convenience. Using their identity smart card with the substation console, tells them which box and unlocks the box. They can then use one of the enhanced shopping trolleys to wheel the goods to their home or business.

Electronic guideways can be extended throughout the area, through paths not required for pathways to or from substations. This allows various types of automated goodspods to service residents and businesses directly at their premises. Automated goodspods of different types can deliver mail, pick up various types of rubbish, pick up and deliver goods into or from a goods box, all directly, from or to, each individual local area business's or resident's property. Specially designed pods may also provide a number of automated guideway or related road maintenance or roadway gardening services.

The guideway extensions could also provide parking space for podcars which was out of the to or from substation pathway. This could even be into the driveway of private properties. Consequently residents or local businesses could order podcars or goodspods to be delivered directly to, adjacent to or close to their properties. There may be extra charges for this, particularly when a vehicle spends excessive time waiting for the user. Similarly, podcar or goodspod's users would be able to direct the podcars or goodspod to one of these parking spaces to allow users and luggage to exit the vehicle.

As the system became heavily used, it is envisaged that the system's pricing structure would make it attractive for the carriage of goods to occur in off peak or night time. As well as the earlier mentioned height limitations there would be additional limitations on maximum axial weight to ensure that there was far less ground vibration than occurred previous to the new system being implemented.

Cooperative Design

Previous High Capacity PRT (HCPRT) network designs have been attempted by single states or single countries. Typically these have been funded by that state's government. A central reason for the funding has been the attempt to make that country dominant in the manufacture and supply of such networks.

It is the view of this author, that the world's need for this type of network should be taken at the primary reason for its design, development and test. That is, the achievement of the objectives such as the reduction of pollution and reducing the deaths and injuries due to road accidents etc. As such, the need for this to be designed should be treated in a similar manner to that of reducing global pollution. That is, it is best achieved as a cooperative effort across a large number of states or countries.

The example of the very successful Vienna Convention and Montreal Protocol for protection of the world's ozone layer shows that cooperative efforts can work. Treating the job of design, development and test in this manner is in many ways simpler and easier than that of global pollution agreements due to the following:

- There isn't any need for all countries to participate. In particular, there is no need for developing or poor countries to participate unless they want to.
- The cost to each country or state to take part in this design, development and test is very much lower than that required from the pollution agreements.
- As well as sovereign states, states within countries can join.
- While it is anticipated that only government organisations that have joined will have voting rights or project control, other organisations such as vehicle manufactures and universities can gain advantage by donating resources to the project.
- Each country or state that participates gains significant advantages.
- The earlier a country or state starts to participate, the more advantage they will gain.

A cooperative effort by a significant proportion of the industrialised nations will make the cost to each state or country very small. The design itself is naturally modular. It is very easy for the various parts to be designed, developed and tested in different countries.

While final implementations should not be connected to the internet, the backbone communications system linking all the control elements will be an Intranet that is compatible with the internet. Consequently, for design, development and test purposes, the internet can be used for communication purposes allowing for example, software to run in one country controlling test vehicles in another part of the globe.

It is envisaged that the various states and countries that take part in the design, will do so primarily by taking on the design, development and test of various components, with the various transportation authorities employing these designers. Ultimately, these designers become the experts in this type of system so when the state employing them ultimately implements the network, they are likely to have less problems.

Design, Development and Test Phases

Early phases of Development should include the following:

Promote the overall concept to all states and nations. Bring into the cooperative as many as possible nations, states and other that will contribute to the development.   The type of development done in this early phase is likely to include the following:

- Create animated films that demonstrate the concepts.
- Create working scale models
- Preparation for the following phases

Settle on an overall design such as the one outlined herein. Note that designs such as this are likely to change as development progresses.

Create initial standards and/or agreements for the various design details needed in order to have compatible systems world wide. Following are some examples of what this should include:

- Vehicle track width, wheel size, maximum vehicle width, maximum vehicle height, maximum vehicle weight.
- Maximum length of platoons, length of time slots.
- Sensors for vehicle position and tracking. Position and number of objects in the guideway that are to be sensed by the sensors. This should include backup systems.
- Type of communication between vehicle and system control elements and between vehicles.
- Message Protocols for messages between vehicle and system control elements and between vehicles.
- Message encryption.
- Definitions of messages
- Specifications (position, size, shape, voltage etc) of the supply rails/catenary lines

Note: Some of these may still require research such as whether to have rare and small power charging supply rails/catenary lines with capacitor banks or ultracapacitors (see section on Vehicle Design: Power) in vehicles. These details can be changed later whenever research has shown more optimal methodology.

At least one, and preferably several of the nations involved should be creating full test tracks. A full test track will need large guideway lengths. This is expected to be greater than 100 km of guideway.

The likes of Australia with many government owned large and flat desert like areas combined with a well educated population makes it an ideal place to position such a test track. For reduction in costs, most of this can be built at ground level without fences so long as there is a method of keeping out people who might inadvertently stray in front of vehicles travelling at 160 km/hr. Rather than the cost of test tracks just being borne by the countries hosting them, other countries in the cooperative should contribute to the costs.   This could be by contributing other parts such as the vehicles. The test track will continue to have a purpose well after design completion and full implementations exist. For example, as a way to test new versions of software.

Control Systems:

The design must be built for resilience, robustness and adaptability. This requires that the whole system doesn't stop for individual breakdowns or non functioning parts. Major requirements for this include:

- Create all control components as low-cost platform and hardware independent modules.
- All designs should be open source
- Design each component to be modular, scalable and extensible. Examples of how this is achieved include the following:
    - Central control and other controls only enhance an otherwise running system. ie. non critical.
    - Individual system components such as intersection controllers and guideway controllers are able to operate in an autonomous manner.
    - High autonomy of vehicles so break downs in central control, intersection control or guideway control components doesn't bring the system down.
- Quick handling of broken down vehicles.
- Major control systems have a triple system type hot backup arrangement with continuous comparison of results with automatic two versus one having priority.

Central Control:

The central control system or a number of central control systems would be used to implement the following:

- Tolling(i.e. charging users)
- Monitoring of all subsystems
- Maintenance of all subsystems
- Central control console
- Security camera (audio video surveillance) access
- Requests for help
- Emergency procedure override
- Updating software and data on all vehicles
- Optimising positions of HCORT vehicles to reduce passenger wait times for vehicles.
- Night-time or off peak parking of unused vehicles
- Ensuring all vehicles using the new system have needed maintenance and testing.
- Route advisory.

Note that all of these are non critical functions. The central computers can fall over without the overall transportation system coming to a halt. Lower level parts of the system, particularly the vehicles, all have alternative operational modes that are activated when the vehicle cannot communicate to the central control or other controllers.

Synchronous versus Asynchronous:

Automated Vehicle Control Systems can generally be classified as 'synchronous' or 'asynchronous'. The typical implementation of synchronous system control is to allocate equally spaced time slots to each vehicle travelling on a guideway. Synchronous system control makes it easier to plan a vehicle's journey and assign resources to it. Synchronous system control is sometimes called 'clear path' as it should normally mean that once full journey resources have been allocated, the vehicle can complete the journey without further conflicts in allocation.

Note: Even with synchronous control systems there can be allocation conflicts. For example, rather than reserve a substation bay at a final destination for a vehicle performing a long trip, this allocation may be delayed on an expectation that one will be available. In general, parking bays are problematic due to the following:

- We don't know when people will enter the vehicle.
- People can hold doors open to stop vehicles leaving when the automation controls attempt to make vehicles leave.

If the expectation of an available parking bay turns out to be false then the vehicle would have to continue travelling (probably in a loop) with an offer to the vehicle occupants of alternative destinations.

In this situation, once the vehicle arrived at the destination without having a substation bay allocated, the vehicle is effectively in asynchronous control. Asynchronous control systems are analogous to the control of vehicles by human drivers. They perform their movements without full pre-planning and adjust speeds and, in some cases, routes as needed.

For safety, synchronous networks needs to also be able to operate in an asynchronous manner, either for specific vehicles that need it in situations similar to the above or for all vehicles under emergency conditions. Examples of other conflicts that can occur include the following:

- Conflicts created when HCORT emergency vehicles such as ambulances, fire engines and police cars have overriding priority.
- Conflicts created when a vehicle on an HCORT freeway lane detects an intruder into the lane such as an animal and slows down to such a slow speed that all following traffic are quickly forced to slow down also. In such a situation, it is preferable that only those vehicles closely following are affected and that remaining parts of the freeway lane can continue their function at their original speeds.

Both synchronous and asynchronous controlled networks need long buffer zones related to each merge and diverge. The buffer zones allow vehicles to alter their speed such that they re-arrange the time they enter the next lane.

For turns into sidings and for re-entering the HCORT freeways from the sidings the easiest place to add this buffering will generally be to add length to acceleration and deceleration lanes but with sidings, the siding itself is also used for buffering.

With asynchronous controlled networks, regardless of having those buffer zones, when the system becomes busy there becomes high likelihoods of conflicts where the vehicle ends up being rerouted in sub optimal ways. With synchronous systems, most conflicts are resolved previous to the vehicle leaving their origin.

Central Route Advisory Concept:

While we want a distributed set of individual system components such as intersection controllers and guideway controllers to operate in an autonomous manner, this can be cumbersome for the allocation of time slots or platoon positions.

For example, assume a vehicle first gets a time slot/platoon position assigned on the first HCORT section of its route only to discover that when it requests a time slot on the next section or any later section of the route, it can't get one that matches up. It now has to go back get the initially assigned position unassigned and then attempt to get a later time slot/platoon position. In busy periods this may repeat several times and may occur with a high proportion of vehicles. This creates many messages, is very inefficient and can end up being very slow. Vehicles and their occupants, sitting in substation bays, would end up waiting for this to complete before their vehicles can start their journeys.

A central control module that has knowledge of all time slots on all routes would be be far more efficient. The problem in having a central control module perform route assignments like this is that this breaks many of our design objectives. In particular, central control needs to be made non critical. This requires that central control modules only enhances an otherwise running system.

To get the best of both worlds we can have a distributed set of intersection and/or guideway controllers performing the actual allocations but we can have one or some additional central control module(s) acting as route advisory module(s).

For vehicles to be assigned a route, the vehicle would normally start by sending a message to the central advisory module. Using the data it has of the whole network, the central advisory module would respond with a complete route of timeslot/platoon positions. With this data, the vehicle now messages each of the distributed intersection and/or guideway controllers to get those timeslots/platoon positions allocated.

Under various (but rare) circumstances, vehicles can go direct to the distributed set of controllers to get their allocations. In these circumstances the advisory module would be updated soon after so there may be periods when the advisory module doesn't have the latest information. Consequently, it is possible for a vehicle to be advised of a complete route of timeslot positions where one or more of the timeslots is not actually available.

In such a case, the vehicle would not get their requested timeslots/platoon positions allocated. Typically, in such a case, the vehicle would wait in the substation bay until they got another suggested set of timeslot positions and ultimately got them allocated. As this situation is rare, the odd occurrence of it will not impact the efficient running of the network.

The route advisory module normally assumes that if it advises a vehicle of a set of timeslot positions, these will not be available for another vehicle. Another rare occurrence that can happen is that the route advisory module can advise a set of timeslot/platoon positions to a vehicle but the vehicle doesn't use that data. This could occur with someone stopping the vehicle from leaving a substation bay. In any circumstance where a vehicle doesn't use that data, it needs to tell that to the route advisory module.

Control system for sidings:

The control system for sidings must take into account the maximum possible length of a vehicle. Let us assume here that this is 9 metres. Note: Such a 9 metre vehicle would need to be significantly rounded at the ends in order to negotiate the turns being envisaged for this system and would not be allowed in ordinary substation bays.

A synchronous control system is easier done without the possibility of long platoons. Since we have to allow up to something like 9 metres for the length, we could also allow platoons of 2 vehicles latched together on sidings but only when those vehicles were 4.5 metres or less along with an assumption that the typical passenger vehicle was 4.5 metres or less long.

We can set a time slot of 4 seconds per vehicle or pair of vehicles. This doesn't have to match the time slots on the HCORT freeway as there will be buffering between these guideways.

For synchronous systems, the whole guideway does not have to have the same speed. Various speeds can be assigned to various parts of the guideway so long as:

- all vehicles that go down those parts of the guideway travel at the assigned speed for that part of the guideway.
- the assigned speed provides a reasonable headway given the maximum length of a vehicle.

For the purposes of this analysis the headway is the distance from the front of a vehicle or platoon to the front of the following vehicle or platoon. Consequently they must be able to contain the maximum length vehicle/platoon plus have some additional gap between the back of the vehicle/platoon and the following vehicle. With the assigned 4 second time slots the headways at different speeds are as follows:

80 km/hr - 88.89 metres
40 km/hr - 44.44 metres
20 km/hr - 22.22 metres
10 km/hr - 11.11 metres
5 km/hr - 5.55 metres

The first 4 of the above are all reasonable headways for automatic controlled vehicles at the specified speed with a maximum length vehicle. The standard assigned speeds for each section of the siding guideway would always be 10 km/hr or more. The 10 km/hr would be the minimum used for very sharp bends.

The last of the above at 5 km/hr(walking speed) is not reasonable, even though most of the vehicles are 4.5 metres or less long. If some situation occurs where a vehicle has to slow down to walking speed while on the guideway, that vehicle and vehicles coming directly behind will have to be changed from synchronous to asynchronous control.

For example, a vehicle detects an intruder into the guideway lane such as an animal and slows down from the assigned speed of, for example, 20 km/hr. Lets assume that the situation clears before the vehicle had slowed below 10 km/hr. Regardless of the fact that the speed is still within the speeds allowed for synchronous control, the vehicle needs to be changed from synchronous to asynchronous control.

While it can now go back up to the 20 km/hr of the section, in order to put it back into a synchronous time slot it must now be controlled so that it is in one of the following time slots 4, 8, 12... seconds after the one it was in. All the following vehicles will be similarly shifted back in time slots (by slowing them down) until there was enough empty time slots to cover this rearrangement.

Each of the vehicles that underwent this rearrangement of time slots would now need the resources for the rest of their journey, to be re-assigned. There may be a period of time where some of these vehicles don't have assigned resources (clear path) for all their journey. They would be partially in synchronous mode as they were now being controlled in synchronous time slots on this guideway but they don't have clear path through out their journey.

In this situation these vehicles would have priority of assignment of resources over those waiting at substations to be assigned their trip resources.

Let us assume that these vehicles were on the siding heading towards the HCORT freeway. Each of these vehicle needs to be assigned a place on the HCORT freeway before it enters the acceleration lane. If any fails to get a place before it reaches the exit or near the exit of the siding it will have to come to a stop and wait for an assignment. All following vehicles will similarly have to stop behind it and wait for re-allocation to get into the HCORT freeway.

The vehicles do not have to be allocated clear path for all the journey in order for them to continue onto the HCORT freeway. They only need to be allocated a place on the HCORT freeway.

Once they have entered the HCORT freeway without full clear path allocation for the rest of their journey, the possibility exists that they will not find slots to make turns into other HCORT freeways or into sidings that would make their journey optimal. In each such case, when they reach that turnoff without gaining an allocation they would simply continue onwards in the HCORT freeway they are in.

The HCORT freeways all have U turns at each end of them. This makes each HCORT freeway an infinite loop. Once a vehicle has been allocated to a platoon time slot on an HCORT freeway it has this place, above all other vehicles, even above those with high priority. It can only be re-allocated after this vehicle has been allocated a place on an exit guideway.

Y intersections and offshoot freeways are slightly different in the implementation of the infinite loop. The infinite loop is implemented to incorporate all the branches within a single infinite loop. That is, at each of the non full cross road intersections, the guaranteed time slot occurs when the vehicle turns in the direction away from oncoming traffic. Note: Offshoot freeway, refers to a Capital T junction of a bidirectional freeway where there's not a full cross road intersection.

Control System for Side Lanes

Note that there is a completely different control system for the side lanes of the sidings which is mentioned in various parts of this document but not fully detailed herein.

HCORT Freeway Control System:

The combination of platooning and variable vehicle length makes asynchronous control systems more difficult than normal but they can be done. For the HCORT freeways, timeslots need to be allocated to the platoons rather than the individual vehicles. The following provides a possible or likely analysis based on the envisaged speed of 160 km/hr for HCORT freeways.

We can set a maximum length of platoon as being, for example, 44 metres. With a typical passenger vehicle length of 4.4 metres this provides a maximum of 10 typical vehicles per platoon. At 160km/hr this maximum length requires almost 1 second to pass a point.

We can set a time slot of 3 seconds per platoon. This very generously provides a 2 second gap between one maximum size platoon and the front of the next platoon at 160km/hr. A small part of this would be used for adding vehicles into the platoon or for vehicles to exit the platoon.

Let us now assume that at some point in the freeway we need a curve that is too tight for the vehicles to safely travel at 160km/hr. As the vehicles approached this curve we could reduce the speed of the vehicles to, for example, 80 km/hr. A maximum size platoon would now take 2 seconds to pass a point and there remains, within the 3 second time slot, a minimum 1 second gap between the back of a platoon and the front of the following platoon.

This demonstrates that there is significant latitude in speed. Even in a synchronous system, the speed can be significantly changed in one part of a freeway without affecting the speed of vehicles in another part, allowing the system to continue in synchronous mode. The throughput of the freeway (i.e. number of vehicles per second passing a point) in this slower section actually remains the same as the throughput in the faster section.

Throughput Calculations.

Example 1:

The above control example, which included the ability to slow to 80km/hr, provides for the following for each HCORT freeway lane:

maximum of 10 vehicles/platoon
1 platoon/3 seconds
10 vehicles/platoon x 20 time slots/minute x 60 minutes/hr = 12,000 vehicles/hr per lane

This compares with a maximum of approx. 2200 vehicles/hr per lane on a standard freeway. The HCORT lane has a maximum capacity greater than 5 standard road freeway/expressway lanes.

There are various ways of looking at this in terms of throughput per area used.

Because the tracking of HCORT vehicles is tightly regulated and the lanes are restricted to only small vehicles, a pair of HCORT lanes takes up a similar area to one standard roadway lane. Consequently, utilising the area needed for one standard roadway lane provides for the equivalent of over 10 standard freeway lanes of traffic.

An HCORT freeway lane will have acceleration and deceleration lanes along a large part of its length. The total width of the HCORT freeway lane plus the acceleration or deceleration lane will be similar to the width of one standard roadway lane. If one includes that, then the area needed for one standard roadway lane only provides for the equivalent of 5 standard freeway lanes for its first lane.

When adding extra HCORT freeway lanes, there is no need for extra acceleration or deceleration lanes. Just as with a standard road freeway/expressway, vehicles will enter the outer most lane and only enter other lanes by merge/diverges across lanes at freeway speed. For these extra HCORT freeway lanes, the area needed for one standard roadway lane provides for the equivalent of over 10 standard road freeway/expressway lanes of traffic.

Example 2:

If HCORT freeways were implemented such that the full speed can be maintained throughout the freeway and the minimum gap between the end of one platoon and beginning of the next was set to a half second (22 metres), then the maximum capacity would be double that shown in the previous example. Calculations for this are as follows:

maximum of 10 vehicles/platoon
1 platoon/1.5 seconds
10 vehicles/platoon x 40 time slots/minute x 60 minutes/hr = 24,000 vehicles/hr per lane

The HCORT lane has a maximum capacity of 10.9 standard freeway lanes. The area needed for one standard roadway lane would provide the equivalent of over 21.8 extra freeway lanes of traffic.

Example 3:

Should a system as specified initially, including the tight turn at 80 km/hr, run out of capacity, it could change the setup to get extra capacity using the following:

Maximum Platoon length is 88 metres
maximum of 20 vehicles/platoon
1 platoon/5 seconds
20 vehicles/platoon x 12 time slots/minute x 60 minutes/hr = 14,400 vehicles/hr per lane

The 3 second gap between the end of a maximum length platoon and the front of the next platoon is needed in order to allow the system to slow to 80 km/hr and still have a minimum 1 second gap between platoons.

The HCORT lane has a maximum capacity greater than 6.5 standard freeway lanes. The area needed for one standard roadway lane would provide the equivalent of over 13 extra freeway lanes of traffic.

Example 4:

The above examples have assumed that the speed on the HCORT freeway is 160km/hr. There is no absolute reason why the speed should set at that. It could well be significantly faster or slower. There are advantages and disadvantages of each speed. For example, a faster speed either requires longer acceleration lanes or more powerful motors. The direction of vehicle technology is to make it easier to go faster and it could well be that the system is implemented at 200km/hr.

The following assumes 200km/hr with some bends that require the speed to decrease to 100km/hr. It assumes that a typical HCORT vehicle is 4.0 metres long and platoons have a maximum of 14 vehicles/platoon. This provides for maximum platoon length of 56 metres. At 200km/hr a length of 55.55 metres is travelled each second.

Setting the time slot to 2.5 seconds allows the gap between platoons to decrease to about half second when at a bend that requires the lowest speed. This would be made reasonable by requiring that under these circumstances it doesn't allow merges and diverges near the bend.

maximum of 14 vehicles/platoon
1 platoon/2.5 seconds
14 vehicles/platoon x 24 time slots/minute x 60 minutes/hr = 20,160 vehicles/hr per lane

The HCORT lane has a maximum capacity greater than 9 standard freeway lanes. The area needed for one standard roadway lane would provide the equivalent of over 18 extra freeway lanes of traffic.

Vehicle Utilisation:

Statistics on freeway use have shown that there is typically 1.2 people transported per vehicle on a normal freeway.

If the new HCORT system operated only with the public transport vehicles being for the "exclusive use of an individual or small group travelling together by choice" then the number of passengers transported per vehicle will also be close to this 1.2 per vehicle.

It is anticipated that the public transport vehicles will be "available for the exclusive use of an individual or small group ..." throughout day and night but have an additional option in peak periods. Although optional, there would be substantive incentive(s) to utilise it. For example, users that required exclusive use in peak periods would be charged significantly higher fares.

The additional option provides a strategy to increase the per passenger per vehicle utilisation. It will work as follows:

The booking/request (i.e. mobile phone app or device at substation) for vehicle system will provide the control system both the location where the user is travelling from and the destination. The control system will try to match requests.

If a user enters a vehicle in a peak period without a booking/request, after the user has entered their destination, the control system will attempt to find other users to share the vehicle. This would include displays that showed the substations that were appropriate for sharing this vehicle. Such displays would be on both the vehicle and the substation bay.

When the vehicle is full or after a specific time attempting to get it full, it will perform the journey.

There would likely be an acceptance of another passenger where that other passenger was going to a different substation but it was in the same direction. This may be limited to substations on the same siding as the first passenger in the vehicle. Alternatively, it could allow for going down different sidings in the journey. It would limit this so that a passenger would only have to wait for the vehicle to go down a maximum of one siding not needed for their journey.

When passengers alight previous to the end of the vehicle's current journey, the substation bay and/or vehicle will display where the vehicle is going to and attempt to replace them if possible. If there were passenger(s) immediately available it will take them but there would not be any significant wait.

Many cities have a traffic pattern where the majority of people are heading towards the city in the morning and returning home, away from the city, in the late afternoon.

The small substations in the outer suburbs are likely to have several bays where one bay could be specified as for people heading towards the CBD and one specified for people heading away from the CBD.

In the CBD or nearest to the CBD the substations would have a large number of bays. Most bays would be reserved for people going to specific destinations or range of destinations.

One advantage of transport systems like this compared to standard roads is the ease in which strategies like this provide for high seat utilisation.

Operation in Reverse:

All HCORT vehicles must be able to operate in reverse. The most common uses of this are in sidings and side lanes. Typical places it may be used are entering and leaving substation bays, entering and leaving properties and performing 3 point U turns. Each of these places it would be used at slow speed.

Vehicles must also be able to travel backwards on HCORT freeways, acceleration and deceleration lanes and sidings at a substantive speed, although this is expected to be a lot slower than the normal HCORT freeway speed. This is needed in the case of accidents and similar events.

For example, assume a large wind blows a roof off a house and onto an HCORT freeway guideway such that the first vehicle to encounter it is unable to stop in time. Assume that following vehicles are able to pull up in time but we need an ambulance for the people in the first vehicle. Now the quickest way for the ambulance and other emergency vehicles to arrive is for the use of an HCORT ambulance using the HCORT freeway. The problem with that is that there may be a number of vehicles between the last exit and the accident. These vehicles can't forward past the house roof and smashed up vehicle. They need to be able to back up to and into the last siding in order to clear the way for emergency vehicles. The emergency vehicles can then travel directly forward to the accident site.

Backing also provides a second route to the accident site. The vehicles just past the accident will continue unaffected and clear the guideway after the accident. Central control can also stop any more vehicles entering the guideway from the sidings that are just after the accident. Once the guideway past the accident has been so cleared, emergency vehicles can get onto that guideway past the accident and then travel backwards to the accident. The easiest places it can use to get onto that guideway would be simple turns or U-turns which exit onto that guideway. It may also be possible to get onto that guideway through a siding but that would require removing any vehicles in the way such as putting them into substation bays, putting them into the side lanes or getting them to exit through the HCORT freeway guideway.

Configurations/Topology/Topography

Access for Traditional Road Traffic

The new system is able to handle the majority of people and goods transport, but not all. A complete implementation for a city could ultimately replace all trains, buses and trams as well as the majority of road traffic.

Remaining road traffic would generally be goods that could not meet the size constraints such as carriage of large cranes, cherry pickers, construction vehicles and carriage of larger items along with vehicles and trailers leaving the city. In order to allow these to be driven to and from where they are needed, each alternate arterial or distributor road or every third or fourth arterial or distributor road along with most highways and freeways will remain unhindered for their use.

Most roads being used by the new system will still have enough room left on the road to allow these vehicles access via side lanes but in order to allow this, traditional street parking will be stopped or substantially reduced.

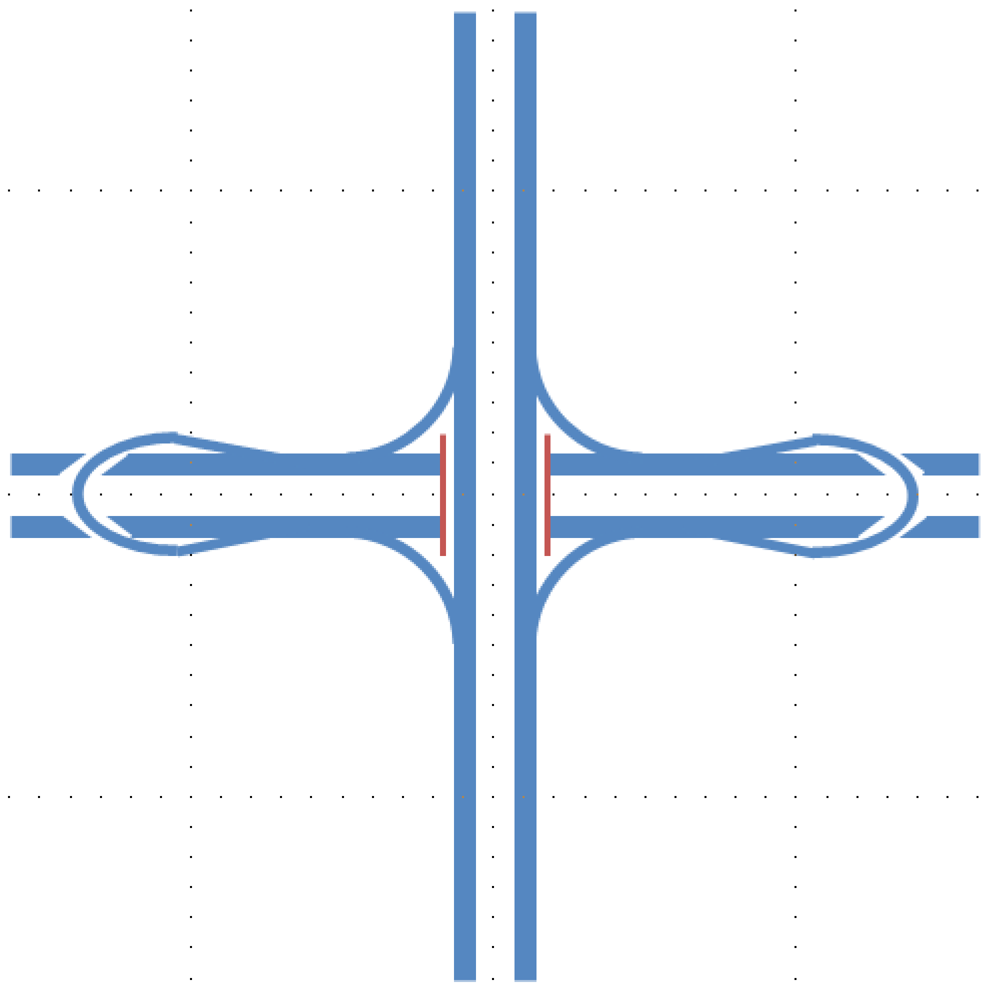
Intersecting HCORT Freeway Interchange Configurations:

When HCORT Freeway Guideways intersect with each other they will be grade separated by elevation. That is one HCORT Freeway going over and one going under. These freeways need methods to turn in both directions. With traditional road freeway/expressways there are common ways of doing this such as the Clover Leaf Interchange.

While each of the different forms of free-flow interchange that traditional road freeway/expressway use such as clover leaf could be used by HCORT interchanges, the recommended one herein is one that is hardly ever used by standard road freeway/expressways. This herein recommended one is the U-Turns Interchange.

Like most interchange designs, the U-Turns Interchange has for each direction of traffic, Simple Turn Lanes from the direction being travelled to the direction away from opposing traffic. That is, if vehicles of a bidirectional pair of guideways travel on the left hand side then these are turns to the left. If they travel on the right hand side, these are turns to the right. For the purposes of this document, these turn lanes are called 'Simple Turn Lanes'.

The Minimum U-Turns Interchange has two grade separated U-turn Lanes on one of the bidirectional freeways, one in each direction. The entrance to these U-Turn Lanes is situated after the completion of the Simple Turn Lanes. That is, if a vehicle travels straight down the freeway containing the U-Turns, it first passes the entrance from the opposite direction's U-Turn Lane, then it passes the exit into the Simple Turn Lane, then it crosses under or over the other freeway, then it passes an entrance from the other freeway's Simple Turn Lane and finally it reaches the entrance into the U-Turn Lane that it is able to enter.



A diagram of the minimum U-Turn Interchange

Using this interchange configuration, vehicles travelling in any direction are able to make any turn including U-turns. That is they can make a left turn, a right turn or a U-turn regardless of which direction they were initially travelling. All of these turns are free flow. This includes turns both from and to the freeway that doesn't have U-Turn guideways.

Some of these turns require combining multiple turn lanes. The most complex is performing a U-turn while travelling on the freeway that doesn't have U-turn Lanes. To do this the vehicle makes a simple turn followed by a U-turn on the other freeway followed by travelling to the other U-turn, making another U-turn and then finally making a simple turn back into (but in the opposite direction) the freeway it was in previously.

The above Minimum U-Turns Interchange can be expanded to have pairs of grade separated U-Turn lanes on both freeways. These extra lanes provide full redundancy for every turn lane or the straight through paths. That is any turn lane, or the straight path under or over the other freeway, can be out of operation with the remaining paths providing a route to complete any turn, including U-turn, or straight through journey. In a 24 hour network we need this in order to perform maintenance on the interchange lane guideways.

This Expanded U-Turn Interchange is herein the recommend interchange to be implemented for the intersection of HCORT Freeway Guideways. Other advantages of this interchange include:
  - It makes U-Turns easy. Other aspects of this HCORT design mean that there will be a higher frequency of U-Turns than the other turns. The way HCORT configurations are designed herein with one way sidings entering the HCORT freeways mean that vehicles are often entering in the opposite direction to that required for their journey. A similar problem exists for vehicles exiting to sidings.
  - It maintains all the intersection on just two levels (grades) and the heights between those levels.
  - These U-Turns are a lot more compact than configurations such as clover leaf. Implementation in a tear drop shape will typically allow the U-turn lane to be implemented without requiring external properties to be purchased.
  - Maximum turns per turn lane are only 180 degrees rather than the 270 degrees of cloverleaf lane, but vehicles may have to implement more than one turn lane to complete their change of freeway.
  - The four Simple Turn Lane guideways plus four U-Turn Lane guideways per intersection produce the possibility of production line techniques with off-site manufacture.
  - Alternative routes can be used by the central control to find a route that has a clear-path to the destination within the various synchronous time slots.
  - The long lengths of the U-turn lane guideways provide greater capability for buffering in order to synchronize the coming merge. Note that the simple turns may need their length increased above that needed for the turn in order to provide greater capability to buffer the traffic to allow each vehicle to synchronize into the coming merge. See below Variant U-Turn Intersection.

Variant U-Turn Interchange.

There is a variant to the above described U-Turn Interchange which I call herein the Variant U-Turn Interchange. To the freeways containing U-turns, this variant adds a side lane from which each of the turns can be made. This allows the order between simple turn and U-Turn to be changed. For example, it can extend the Simple Turn Lane so that it connects into the entrance of the U-Turn lane and allows vehicles to enter the destination freeway after the U-Turn lane.

This author is not aware of any road that uses the standard U-Turn Interchange exactly as described earlier but there is one example of a Minimum Variant U-Turn Interchange built on the Dongbu Expressway in South Korea. This can be seen on google maps at:

https://www.google.com/maps/place/37%C2%B033'35.8%22N+127%C2%B004'19.5%22E/@37.5597444,127.0732187,16z/data=!4m5!3m4!1s0x0:0x0!8m2!3d37.55994!4d127.072071?hl=en

An expanded version of the Variant U-Turn Interchange may be a better option for HCORT free interchanges as it provides longer length for buffering in order to complete synchronization of vehicles in the coming merge of their journey.

HCORT Freeway Guideway to Road Configurations:

In the outer suburbs the HCORT freeways will go along the centre of roads that were previously minor arterial or minor distributor roads. Road changes required due to placing this guideway in the centre will often involve changing the function of the road to simply being for local traffic.

There are a number of options on how to place HCORT freeways and sidings. The main ones are as follows:

> **A)** Place a bidirectional pair of HCORT freeway guideway lanes in the centre of an arterial/distributor road. This may be significantly cheaper than options B: or C: below but this primarily depends on the cost of the fencing and the costs associated with adding U turns. It also depends on if there is enough room in the arterial/distributor road for these and associated acceleration/deceleration lanes while still providing sufficient roadway use for standard traffic such as access to properties.
>
> The primary advantage of this configuration (compared to B: and C: configurations) is that the cost to fence the pair of HCORT freeway guideways will be similar to the cost to fence just one of the single direction HCORT freeways and both need to be fenced. There may also be reduced costs in having fewer but larger overpasses/underpasses along the length of the HCORT freeway guideways. When the pair of HCORT freeway guideways become elevated there may also be cost savings in the pair of guideways being able to share foundations and support.
>
> In this configuration, sidings, both entry and exit, are expected to only connect into the HCORT freeway guideway on the same side of the arterial/distributor road as them. That is, they only connect into the nearest freeway guideway, not the one in the opposing direction.
>
> This means that turns from the sidings into the HCORT freeways (via acceleration lanes) will often have to be done such that the vehicles on the HCORT freeways are going in the opposite direction to that wanted. The vehicles would then perform a U-turn to go where they wanted.
>
> A similar problem exists for vehicles attempting to enter a siding. Their journey will often have them travelling on the opposing traffic freeway lane. To get to their siding they will go past their siding, perform a U-turn then on the return to that siding they will be able to make a simple diverge into the deceleration lane of that siding.
>
> Another problem with this configuration is that it assumes that there is a reasonable route for sidings to travel around some block or blocks of back street, or at least it assumes it for the initial implementation.   It is preferable for it to travel around some block or blocks as that allows the siding to be implemented as one way lanes.
>
> This will not always be the case and the siding will then have to be implemented with two guideways down the back street in order to return the traffic from the siding. It may also require the vehicles to perform a U-turn on the siding. If the siding has very low traffic it may be possible to implement a time multiplexed single lane with bidirectional traffic.

Note that this type of problem will only be a problem in the early implementation of a city. As more HCORT freeways become implemented such that there is another HCORT freeway one, two or three blocks over, then some of the sidings will be converted to allow travel across to the further away HCORT freeway.

B) Place a single direction of HCORT freeway guideway on one arterial/distributor road and place the opposite direction of HCORT freeway guideway on an arterial/distributor road that is roughly parallel but one block over.

Some sidings would go as one way guideways in one direction between the HCORT freeway guideways and some would go in the opposite direction.

In the early stages of implementation, previous to there being more HCORT freeways out to each side, there would be some sidings that travel around some block or blocks of back street and return to the same HCORT freeway guideway, in a manner similar to that required in A: above. This is required for all sidings on the outside of the bidirectional pair of HCORT freeway guideways.

The advantage (compared to A: above) are as follows:

- Only requires a single lane guideway plus associated acceleration/deceleration lanes in the middle of the road used for the HCORT freeway.
- The sidings can be used to implement U-turns. These U-turns would be slow and would add extra traffic to the sidings.
- This adds to the transport network coverage.

C) Place a single direction of HCORT freeway guideway on one arterial/distributor road and place the opposite direction of HCORT freeway guideway on an arterial/distributor road that is roughly parallel but two blocks over.

The disadvantage of this (compared to B: above) is that most of the sidings will require crossing the in-between arterial/distributor road, presumably by near grade underpasses.

The advantages of it (compared to B: above) are

- Allows alternate arterial/distributor roads to continue their original function.
- Allows a single pair of HCORT freeway guideways to cover a wider section of the outer suburbs.
- Easier to provide standard road users access to side lanes and consequently easier for ordinary vehicles to reach their own properties.

Back Street Siding Guideway Configurations:

Narrow back streets converted to containing sidings or designed originally for sidings will typically have the following configuration:

- A single one way lane for the new HCORT system near the center of the road. This will generally be fenced off to stop pedestrians crossing it. Note that the fences used here may not be of the same quality as those used for the HCORT freeway guideways.
- Near one end of the road or road block there will be a substation where the HCORT vehicles can park on one side of the road. Near the other end of the road or road block there will be a substation where the parking of HCORT vehicles will be on the other side of the road to that of the other substation.
- At or near the substations there will be a small bridge over the HCORT lane to allow pedestrians and bikes to cross.
- Along both sides of the HCORT system lane, there will be roadway lanes that allows traditional road traffic access to properties along the street. Through access is blocked by the substations. Consequently, these are alternating direction single lanes with the direction and access being controlled by an electronic control. Herein, these lanes are called siding side lanes or just side lanes.
- The electronic control for these can be just a mobile phone app. This app. would require the road user to request permission to travel the roadway lane and the user would state the property driveway that it was going into. It would only be given access to the roadway lane if the property driveway requested was available and it had permission to use that property driveway. It would only be given permission if the mobile phone device provided its GPS location data.

- Automated vehicles designed for the new HCORT system can also go up and down the side lanes. Reasons for them doing this could be as follows:

- People using the system for transport can request a vehicle to deliver them to their driveway instead of a substation. Similarly users can request a vehicle to pick them up from their driveway. This can be particularly important for safety late at night and it would be a major advantage in inclement weather. Except for disabled people etc, one would expect extra charges for this.
- Specially designed automated vehicles to implement various utilities such as rubbish collection, street gutter cleaning, letter and parcel delivery etc
- Automated delivery of goods such as pizza delivery.
- Tradespeople, lawn mowing and garden services etc may use the new HCORT vehicles rather than traditional road vehicles.
- Some of the above services require the vehicles to enter a property's driveway. For driveways to be able to be used for this, they will have to have a number of extra sensors. These sensors will detect things such as, if the gate is open, is there any vehicle or other objects (bikes, toys etc) blocking the driveway etc.

- Problems with the side lanes are as follows:

- When roadworks are needed on the side lanes there will typically be a blockage to property access.
- When street tree pruning with a cherry picker is needed there will typically be a blockage to property access.
- Large property building developments often use a parking lane on the street. Typically, this

will not be available for new developments.

Sidings are often implemented as a loop. The HCORT vehicles go one way away from the freeway on one side road and return to the freeway a block or two away on another side road. This loop along with the freeway will sometimes enclose a road (a back street) and will normally enclose several of the side lanes. Consequently, most such loops require there to be several bridges over the single HCORT lane. These bridges must be able to hold the weight of all traffic able to enter properties. The most common place where such a bridge is required is just before or after, entry or exit to the acceleration and deceleration lanes.

The above design keeps the HCORT lanes (sidings and freeways) completely separate from pedestrians or normal traffic. HCORT vehicles are only on side lanes when there is no normal traffic. There may be situations where it is advantageous to allow a degree of mixed traffic but with the HCORT vehicles driving at a very slow speed. For an HCORT vehicle to enter and exit properties it must cross a footpath and consequently not run over any pedestrians or other footpath users. Possible methods to allow bikes on these roads are as follows:

- Provide a separate bike lane. This is best situated between a side lane and the centre HCORT siding. This must be crossed for the HCORT vehicle to enter the side lane. It is preferable for this crossing to be with grade separation, either the HCORT lane under the bike path or the bike path under the HCORT lane.
- Provide a separate pedestrian + bike path that was elevated. This could be situated over the top of the centre siding lane so that it would only ever need to be just above the height of HCORT vehicles.
- Allow bikes to travel on the footpath
- Require bikes to also use the mobile phone app used by cars to request access to the side lanes.

Implementation:

Initial implementation is problematic as:

- The advantages of the system are not as clear when there is a low number of destinations. The available number of different origin to destination journeys is proportional to the square of the size of the network.
- The advantages of high speed is only felt when there is sufficient length to a journey.
- The initial implementation will not give good reliability as it doesn't have alternative routes to bypass parts of the system that are out of service such as when maintenance is needed. This will be exasperated in the early stages as there will be teething problems.

The recommended initial implementations herein tries to show off the system under these conditions, while reducing the costs and problems of the recommended near grade installation.

The best initial implementation would be for the majority of resident coverage (most of the substations) being from new outer suburbs being built and sold at the same time as the HCORT network is initially installed and the HCORT freeway to be able to carry these people to and from a train station close to the CBD as well as to and from a number of major centres. The advantages of making this the initial implementation include the following:

- This will increase the coverage as many people who can see themselves using this network will purposefully purchase these new properties when they are sold and those with a lifestyle which will likely see them them not using it will purchase elsewhere.
- This will reduce complaints and political fights against the making of the system. Note that the overall effect is that it will increase the value of properties in this area so the land developers should be supporters of it.
- New suburbs tend to be in the far outer suburbs which is the best place for early implementation for a number of reasons discussed elsewhere.
- This makes it easier to design the road system in a way that is conducive to including the near grade network and consequently allows the near grade network to be built economically.
- The long length of HCORT freeway to the train station close to the CBD will show off the advantage of this network's high speed.
- New outer suburbs cause problems with adding extra traffic to already overcrowded roads. This should solve or help to solve this problem.
- New outer suburbs need access to facilities that are expensive to build. This network may allow access without new facilities being built. For example, rather than providing new schools, it may be more cost effective to transport children to established schools in the middle or inner suburbs if these schools are half empty. When schools become half empty due to changing demographics, it becomes very difficult politically to shut the schools down. Similarly, changing demographics can result in swimming pools and sport ovals being in suburbs that have few children.

The following implementation is based on large cities of the style of Melbourne, Australia, where the author of this submission is resident. The characteristics of such a city are as follows:

- A large percentage of travel is to and from the CBD or to and from inner suburbs.
- Public transport within inner city or near city is generally good so long as both source and destination are also inner city or on specific routes.
- The population of the city is expanding at a fast rate. The government has problems with releasing sufficient land for housing which is causing excessive growth in property prices.
- The city has a train system which radiates out from the CBD. Although it branches somewhat as it gets further out, train systems cannot branch out sufficient to directly cover most of the outer suburbs.
- Attempts to provide public transport to the remainder of the outer suburbs use the following:
  ~ Buses along circumferential routes.
  ~ Large parking spaces at outer suburban train stations
  ~ While train travel can be fast when express, for large parts of the train network the travellers have slow journeys where the train stops at a large number of train stations.
- For a large proportion of people in the outer suburbs the total time to travel to their destination by public transport becomes so great that they end up using a car. This is putting excessive pressure on the road network which is not coping adequately with the traffic. The congested road traffic uses a lot more energy and creates far more pollution than public transport. The road traffic also creates a very high death and injury rate.

An HCORT implementation plan for such a city would be as follows:

- The initial implementation would be based on one or more radial HCORT freeways that allowed passengers to go directly to an inner suburban train station where they can get a short express train to the CBD. These initial implementations would also connect into shopping centres, schools, factories, hospitals, police stations, theaters and other centres. The majority of the HCORT freeway and almost all the outer suburban sidings would be implemented at ground level as near-grade guideways with grade separation. As the HCORT freeway approached the inner suburbs, it would run on an elevated track that allowed the original use of the roads below to continue. The main inner suburban substation would be implemented elevated on top of a major train station.
- Initially, most of the substation sidings would be in residential areas in the outer suburbs, particularly the far outer suburbs. It would be easier still if the suburbs were new suburbs, just being created as the new system was implemented. Sidings in inner and middle suburbs would be for access to specific shopping centres, schools, factories, hospitals, and other major centres along with police stations. Note that these early implementations would not connect to sports grounds etc. that had events with large special event crowds.
- The first HCORT freeway would extend outwards beyond the outer suburbs. As well as having night parking for HCORT vehicles, there would be extensive parking for standard road vehicles for those that needed to drive to get access to the new HCORT system along with permanent parking for vehicles owned by residents who have lost their roadside parking.
- The next implementation would include implementing an HCORT freeway guideway roughly parallel but one or two blocks over from the initial implementation. Included with this implementation would be sidings that connected to both the initial HCORT freeway and this new one. There will be a number of sidings running in each direction. These would be created by modifying the initial sidings as well as by adding new ones. Once this has been implemented the transportation network will contain alternate routes that allows maintenance to

some parts of the HCORT freeway guideways while still allowing some journeys to complete.

- After more radial HCORT freeway implementations as above occurred, there would be outer and inner ring HCORT freeways connecting the radial freeways together as a network. Until there was a reasonable network, there would be poor network dependability as maintenance on a HCORT freeway would bring down a large proportion of the use of the complete system, a similar problem to that of railway lines.
- This would first be continued throughout the radius of all the outer suburbs not supported by train lines. The circumferential ring HCORT freeways would cross the train lines to network the various radial HCORT freeways. As they crossed the train lines, HCORT substations would be created at nearby train stations.
- The earlier implementations would be extended to include sidings so that middle and inner residential suburbs had good access.
- There would then be implementations along the train lines, Bus Rapid Transit (BRT) and Light Rail in the outer suburbs, replacing those rail and BRT branches. As by this time, the standard road traffic would be reduced, the land freed up by this replacement could become bike lanes and extra park land although some could be sold for residential use etc.
- Initial implementation within the CBD would be for goods carriages into the various businesses within the CBD.
- As creation of substations in the CBD is after almost all the suburbs have good HCORT access, it will involve a complete level of network throughout the CBD. This would be at elevated levels with substations attached to the sides of most of the large buildings throughout the CBD.
- As or after several cities were implemented, HCORT freeways would be implemented between cities.

Vehicle Design: Power

The vehicles are electric vehicles powered by battery. Power for charging the battery is provided at various places along the HCORT freeways and while parked at substations and other parking bays. At parking bays, inductive transfer is used. Along the HCORT freeways are short sections of catenary lines or supply rails which the vehicles utilise through a pair of collectors (trolley poles, small pantographs or bow collectors). Two supply rails/lines along with two collectors are needed due to the rubber tyres isolating the vehicle from ground.

The best place to put the supply rails/lines is likely to be below the vehicle. The supply rails can be rails that have been set at a raised level above the ground. That is, there is no need for the wheels to run across them as they can always be placed away from any possible guideway merge or diverge.

Due to the problems of skin effect when the supply is AC, it is best not to conduct electricity through the whole rail. Rather the rail becomes a support for a thinner electrical conductor (e.g. wire) which runs on the top or to the side of the rail. If the conductor is to the side then the electrical conductor may be below the rail's top lip. This thin electrical conductor will have insulation between it and the rail or the rail itself will be an insulator. The collectors either rub against the thin electrical conductor or rolls along it with electric conductors that collect and conduct electricity to the vehicle.

The sections of supply rails (catenary lines) on the route are turned on only when vehicles are in contact with them and all the vehicles are at or near full speed for that section. Note that these sections are longer than the length of a vehicle so there still is some possibility of, for example, an animal touching the track while a vehicle is on the track. The requirement for speed detection ensures that the supply rails are off in the case of a major event such as earthquake where people were being evacuated from stationary vehicles by walking along the guideway.

These sections of the route are all well fenced off to stop any person coming onto the track. These sections of the route are away from overhead crossings or any other places where a person could access them or urinate on them as a vehicle goes past. A ground fault interrupter switch will switch off power if any person, animal or object touches one of the rails such that they or it conduct electricity to earth.

Ground fault interrupters are also called 'ground fault circuit interrupters' (GFCI) or 'Residual Current Devices' (RCD). The use of the ground fault interrupter switches requires that there is a method to return the system to normal after a ground fault interrupter switch has been tripped. This could be manually from the central control command station but that would require that each section of supply rail had good video surveillance along the whole length of supply rail along with good lighting. Alternatively it could be automatic. Whether manual or automatic it would be better for the system to be able to measure and monitor the current leakage to ground.

Capacitors (or ultracapacitors or supercapacitors) in vehicles can be used to increase the energy transfer in the sections that the vehicle collectors are in contact with the supply rails/lines. This allows the batteries to continue being charged from the capacitors after the vehicle has passed the short sections of supply rails/lines.

The main advantage of using capacitors is that the guideways can be built with very short sections of supply rails/catenary lines and long distances between them. A more thorough cost analysis of including capacitors versus ultracapacitors versus not including capacitors needs to be done. The following assumes that capacitors are added.

Including capacitors, subsystems in each vehicle to implement the collection of power from the supply rails/catenary lines through to the charging of the vehicle batteries, in the order or route of the energy transfer, are likely to be as follows:

1. Pair of power collectors collects power from supply rails/catenary lines.
2. Input protection. Particularly protection from lightning strikes.
3. Intelligent AC to DC switch mode power supply with active power factor correction. This power supply will control or limit the output current, and consequently the input current, to that appropriate for the system and limit the maximum output voltage to that allowed by the capacitor bank.
4. Electronic switch(s) or diode(s) to disconnect capacitor bank from the AC to DC switch mode power supply when the vehicle is not collecting power.
5. Capacitor bank. Additional inductor(s) and/or resistor(s) may be added to the capacitor bank in order to create a low pass filter to protect the capacitors from voltage spikes.
6. Intelligent DC to DC switch mode power supply converting the varying DC of the capacitor bank to the appropriate battery charging current.
7. Electronic switch(s) or diode(s) to disconnect batteries from the DC to DC switch mode power supply when the power supply is not charging the batteries.
8. Low Pass Filter (may not be needed).
9. Vehicle Batteries.

In recent years, new types of capacitors or pseudo capacitors have come onto the market which have a far higher capacitance per area or per kilogram mass.   These are called supercapacitors or ultracapacitors, two names for the same thing.

The higher capacitance means that they can store a higher amount of energy. The problem is that they don't handle energy transfer into them as fast as do normal capacitors although they handle it better than batteries.

They have slightly different properties to normal capacitors. For example, they don't handle higher frequencies very well. With frequency they substantially reduce their capacitance. Because of this, it is better not to use them for frequency filters.

Including ultracapacitors, subsystems in each vehicle to implement the collection of power from the supply rails/catenary lines through to the charging of the vehicle batteries, in the order or route of the energy transfer, are likely to be as follows:

1. Pair of power collectors collects power from supply rails/catenary lines.
2. Input protection. Particularly protection from lightning strikes.
3. Intelligent AC to DC switch mode power supply with active power factor correction. This power supply will control or limit the output current, and consequently the input current, to that appropriate for the system and limit the maximum output voltage to that allowed by the

ultracapacitor(s).

4. Electronic switch(s) or diode(s) to disconnect ultracapacitor(s) from the AC to DC switch mode power supply when the vehicle is not collecting power.
5. Low pass filter. The capacitor(s) as part of this will be standard capacitors.
6. Ultracapacitor or ultracapacitor bank.
7. Intelligent DC to DC switch mode power supply converting the varying DC of the ultra capacitor(s) to the appropriate battery charging current.
8. Electronic switch(s) or diode(s) to disconnect batteries from the DC to DC switch mode power supply when the power supply is not charging the batteries.
9. Low Pass Filter (may not be needed).
10. Vehicle Batteries.

Another option with ultracapacitors is to use ultracapacitors without using a battery. In that case subsystems in each vehicle to implement the collection of power from the supply rails/catenary lines through to the charging of the vehicle batteries, in the order or route of the energy transfer, are likely to be as for 1 to 6 in the above subsystems.

A more thorough cost analysis of including a capacitor bank or ultracapacitor(s) may find that the overall system is cheaper without including it in the vehicle charging system. The main savings would be the lack of capacitors and lack of DC to DC switch mode power supply.

Without the capacitor bank or ultracapacitors, subsystems in each vehicle to implement the collection of power from the supply rails/catenary lines through to the charging of the vehicle batteries, in the order or route of the energy transfer, are likely to be as follows:

1. Pair of power collectors collects power from supply rails/catenary lines.
2. Input protection. Particularly protection from lightning strikes.
3. Intelligent AC to DC switch mode power supply with active power factor correction. This power supply will control or limit the output current to the appropriate battery charging current.
4. Electronic switch(s) or diode(s) to disconnect batteries from the AC to DC switch mode power supply when the vehicle is not collecting power.
5. Low Pass Filter (may not be needed).
6. Vehicle Batteries.

Without the capacitors, the HCORT guideways would have to have longer and far more of the supply rails/catenary lines. For example, they could be an average of 30 metres long and occur on 20 percent of the guideway's length.

Whether capacitors are included or not, the above battery charging system allow the vehicles to have very small batteries. For example, a battery that would only power the vehicle for 10 kilometres without extra charge would probably be sufficient. This is far smaller than that typically used in electric cars.

For dual mode vehicles with sufficiently large batteries, the addition of this charging system would be optional. Regardless of whether the charging system is installed, all vehicles will need to have the state of their battery constantly monitored along with an appropriate exit strategy if the battery charge is below a reasonable amount.

In countries where heating is needed, power for heating may be extracted either directly after the input protection or directly from the capacitor bank.

Coils embedded within the parking bays are used to provide inductive transfer when vehicles are parked at substations and overnight parking areas and similar. The coils are only energised when a vehicle is parked above it. The coils are energised with an AC voltage.

Each parking bay monitors how much energy is supplied to each vehicle and each vehicle monitors how much energy it receives. These details are sent to the control system which checks that they reasonably match. In this way, the system can recognise if there is any attempt by local residents or others to harness the power supplied at parking bays.

Each vehicle has a power receive coil which, when the vehicle is parked in a parking bay, will be close to the coil embedded in the parking bay just below it. Both the power receive coils in the vehicles and the power transfer coils embedded in the parking bays are wound on appropriate cores which are designed and arranged to provide high magnetic coupling between coils and low energy loses.

Implementation of the collection of power from the receive coil through to the charging of the vehicle batteries should be able to utilise most of the subsystems used in the above supply rails/catenary lines through to the charging of the vehicle batteries.

The receive coil can be connected through an electronic switch to an input to the AC to DC switch mode power supply from 3. in the subsystems above. As well as providing the appropriate AC to DC conversions, this means that the capacitors or ultracapacitor(s) are used to continue charging the batteries for some time after the vehicle has left the parking bay.

The subsystems used on the HCORT freeways for collection of power from the supply rails/catenary lines through to the charging of the capacitor bank can be used at a very high rate of power even if designed without large heat sinks. The reasons it can handle such a high rate of power are as follows:

- It is only used for a very short period of time with a substantial gap between each usage. For example, if we assume that each supply rail/catenary line was 10 metres long and that these were set up at intervals of one kilometre, it would be collecting power for less than a quarter of a second and have a gap of about 22 seconds without power where it can cool down.
- As the vehicles are travelling very fast it should be easy to arrange a good airflow.

The same conditions do not apply to the use of these subsystems for collection of power from the parking bay coils. For this reason the intelligent AC to DC switch mode power supply needs to recognise when it is getting its power from the parking bay coils and control or limit its output to a far lower current than when it is getting its power from the power collectors collecting from supply rails/catenary lines.

Design: Transducers/Sensors etc:

Assumptions.

Need to assume the following:

- There are some people with the mentality that they want to place large rocks on railway tracks or equivalent.
- Some people with this mentality have the capability to create electronic devices such as radio jammers.
- Some people with this mentality have the capability to hack into insecure networks.

A) For each Vehicle to locate its position and track its route.

Need multiple methods of gaining position and track at any point of time. Methods able to be used for position fixing and vehicle tracking:

A combination of the following:

- The vehicles follow one or more frequencies being broadcast from an embedded wire or wires in the ground or otherwise below the current track. This is better than the radio signal trilateration/multilateration as the detectors are so close to the wire there isn't a chance for jammers to stop the vehicles receiving the signal. Problems with it are breakage of wire due to ground movement and loss of signal due to loss of system power. Multiple embedded wires in parallel could be used to cover most ground movement faults except those caused by extreme events such as major earthquake faults.
- Location of position along the wire (a fix) can be done by locating magnets buried in the ground. Magnets can have North or South pole positioned upwards and a group of them can provide a digital number. Magnets may be no more than permanently magnetised nails, bolts or similar embedded in the ground. These magnets can be measured by a number of cheap and easy methods such as Flux-gate magnetometer sensors, Hall effect magnetometers, Magneto-resistive devices or inductive pick coils.
    - Inductive pick up coils require movement between the sensor and magnet.
    - Solid-state Hall effect sensors are the most common magnetic sensing devices where the magnetic field strength is relatively large. These can be mass-produced as an integrated circuit.
    - Flux-gate magnetometers are currently being used in similar applications. They "are affordable, rugged and compact with miniaturisation recently advancing to the point of complete sensor solutions in the form of IC chips"
- One or more continuous lines of magnets may be useful as a way of backing up the embedded wire(s) in case of loss of power to the wires. Several of the currently designed PRT and automated bus systems use similar magnets as their primary source of tracking. The problem

with using it as the primary source of tracking is that there is a possibility of someone throwing some magnetised bolts or nails on the track. That is, as a modern form of placing rocks on railway lines.

- Counting rotation of drive wheels such as counting of stepper motor steps in order to locate distance along from the previous fix. This can be used in conjunction with a history of the steering position. While this data can be used for vehicle tracking, it is herein anticipated that it would only be used as a last resort backup or as a fault detector. This style of measurement suffers from accumulated errors. Consequently it needs frequent resetting or initiating at known set points.
- An inertial measurement unit (IMU) can also be used as a last resort backup or fault detector. As with the above history of steering and drive wheels, this style of measurement suffers from accumulated errors and consequently needs frequent resetting or initiating at known set points.
- Radio transmitters at various distances on both sides of each track. These could be used to give position by triangulation, trilateration or multilateration. Their cost and their transmit distance allows for multiple trilaterations/Multilaterations so that some number of transmitters can be faulty and yet there is still an accurate position fix. Problems with using these for primary vehicle tracking include:
  ~ they would stop working on loss of system power
  ~ they are too easily jammed
- The radio system used for vehicle to central system communications (eg WiFi) could double as a backup position fix in case of emergencies such as earthquake faults, to give an approximate position. One problem with this is that it is still subject to loss of system power.
- GPS is too inaccurate to use as a main system. It may be used as a last ditch backup in the case of emergency. Even to be used in this backup, it needs to have significant corrections such as Differential GPS (DPGS) (and/or WAAS). Specific DPGS stations for this system may need to be implemented to get enough accuracy. Also, an inertial measurement unit (IMU) would be used as an aid for when GPS signals are unavailable, such as in tunnels, inside buildings, or when electronic interference is present.
- While a number of optical methods (including laser) are cheap and accurate, optical methods have problems with dust, snow, hail, rain, fog, insects, buildup of dirt, repositioning after bumps etc.

Notes:

- By having multiple sensors of each type, most of the objects to be sensed such as magnets in the ground or rf transmitters, including wires in the ground, can be positioned inaccurately and the system can allow movement such as can occur with ground movement. For example, in the case of multiple magnet sensors or multiple rf sensors for wires, the sensors would be positioned across some part of the width of the vehicle. Previous to any vehicle utilising the objects in their final application (at their final speed and with passengers) the vehicles are told the position with respect to the sensor positions that the objects should be sensed. This allows the vehicles to accurately position themselves regardless of the inaccurate initial positioning of the objects. The overall system would then monitor differences from the original data as to where vehicles are sensing the objects. Using this data, the system can monitor if most vehicles are seeing a different position or just specific vehicles and from this determine if the changes relate to changes in the guideway or changes in the vehicle. This would be used to correct position data of the vehicles and would be used to initiate appropriate maintenance.

- In order to use alternative systems as backup, you need an orderly plan as to which to use when the two systems are not in agreement. The most common situation will be that one sub-system recognises that it is not able to read the directional information while the other still has a lock on its direction information. In this case, the sub-system that believes it still has valid direction information would be used.
- It would be better to have a third sub-system just for the possibilities that both subsystems think they are OK but they report a different output or that neither sub-system believes they are OK. A possible third sub-system is to use information from measuring the wheel rotation and measuring the steering movements. For example, we may just use the one that is closest to that which occurs when the front wheels are positioned for straight ahead.

- A mechanical or hydraulic steering system based on running tracks can be used as a backup without creating friction by having runner wheels that in normal operation are a short gap away from the running track. This would only come into play when other systems failed such as when the vehicle loses its power. That is, when a vehicle loses all power it would be automatic that the runner wheels would lower, move or close such that they griped or pushed against the running track.

The lowering, moving or closing could be implemented by springs. Holding the running wheels off the track, creating the short gap, could be implemented by electromagnets that are normally on when the system is running normally. A loss of power means the electromagnets turn off, which allows the springs to push the runner wheels to the running tracks.

The running tracks need to be arranged so that they steered the vehicle off the main freeways and onto sidings and off sidings onto side lanes. In the case of vehicle power failure or some other emergencies, the following vehicle would be able to push the failed vehicle, with this mechanical steering system automatically directing it to the best place. Such a system needs to continue working even when the vehicle has a tyre blowout, including a blowout of one of the steering wheel tyres.

B) Faults and emergency danger sensors:

- Radar and/or Ultrasonic and/or Lidar ('light and radar') can be used for detecting emergency situations such as people or animals on the guideways or tree branches or roofs that have been blown on to the guideways.

With this system, it is expected that before full operation of each new freeway, subsidiary extension or part thereof, vehicles are given expected sensor input that was directly derived from sensors of previous vehicles travelling on that part of the route. In order to initially get the sensor input, a number of vehicles travel the new part of the system in test mode.

Before any new vehicle is used, or any vehicle that has had maintenance that may have modified the placement of its sensors, the vehicle is required to run around a test track comparing its sensor inputs to that of an average of test vehicles. Using the differences between its inputs and those of the test vehicles, it sets up an error map. The error map allows it accurately correlate between what it sees on its sensor inputs and what is expected based on sensor input previously obtained from other vehicles via a central computer system.

- Maintaining awareness of and history of steering position along with counts of the rotation of drive wheels can be used as a vehicle tracking fault sensor.

C) Inter-vehicle sensors for Platooning:

- The emergency danger sensors such as Radar could double as Inter-vehicle distance measurements for Platooning.
- Small radio transmitter/receivers can be placed along each of the bumper bars, front and rear. As vehicles come close to each other for platooning, each receiver does a Trilateration or Multilateration with the other transmitters. This may be used to give more precise distance measurements as vehicles are brought together for platooning. The particular frequency being transmitted by each transmitter would be given to these transmitters by the central system, for each platoon connection. Note that unless very high frequencies are used, these transmission/receptions will occur in the transmitters 'near field'. For example, metal objects such as steel beams can act as antennas by inductively receiving and then "re-radiating" some of the energy in the radiative near field, forming a new radiating surface to consider. Main options are:
    - trilateration: To get a distance for trilateration, each receiver transmitter would return the signals (frequencies) received from the other vehicle or some related in phase signal (such as double or half the received frequency). The original transmitter of each signal would compare the phase of the received signal returned back compared to the original sent, in order to measure the distance
    - Multilateration: [12] Each transmitter simply transmits its own frequency. Pairs or groups of receivers work out the "time difference of arrival" (TDOA) to the receivers by comparing the phase difference of the signals received at different receivers. While this requires more transmitters and/or receivers it is simpler to implement and should produce a more accurate output.
- Another alternative for precise distance measurement for platooning is to use a light or laser based system. As mentioned earlier, these have problems with dust, snow, hail, rain, fog, insects, buildup of dirt etc. Having multiple sensors is easy as they are cheap. Finally, if all of the multiple sensors fail (which should be rare) then we can simply not make a platoon connection with these two vehicles.

D) Vehicle to Central System Communication

This could be something like WiFi so long as the data has sufficient encryption to ensure that the system isn't interfered with by hacking or similar. IEEE 802.11p [14] is an approved amendment to the IEEE 802.11 standard to add wireless access in vehicular environments (WAVE), a vehicular communication system. It defines enhancements to 802.11 (the basis of products marketed as Wi-Fi) required to support Intelligent Transportation Systems (ITS) applications.

Dedicated short-range communications (DSRC) [13] is also a possibility but it has incompatible protocols in different parts of the world. Similarly V2V (short for vehicle to vehicle) [15] technology is a possibility but the channel allocation is in doubt and no spectrum has been allocated in Australia.

E) Vehicle to Vehicle Communication

For platooning we need to gain a fast enough response to ensure a following vehicle acts near simultaneous to the vehicle in front. For this we need a direct vehicle to vehicle communication. While this could be a range of communication types, it is probably best as radio. The data has to have sufficient encryption to ensure that the system isn't interfered with by hacking or similar. The communication between each pair of vehicles would be setup by the Central System before the vehicles came close enough to need it. There needs to be a constant data stream within the communication such that both vehicles can detect quickly if there is any break in the communications. In the case of any break of communications, the attempt at joining the vehicles for platooning is abandoned.

This can also be IEEE 802.11p [14]. Presumably this would be implemented with different channels allocated to those used for vehicle to central system communication.

Dedicated short-range communications (DSRC) [13] is also a possibility but it has incompatible protocols in different parts of the world. Similarly V2V (short for vehicle to vehicle) [15] technology is a possibility but the channel allocation is in doubt and no spectrum has been allocated in Australia.

F) For Central System to Locate a Non Communicating Vehicle.

Assume vehicle loses all power when it is meant to be accelerating into the merge on a main Freeway. How can an oncoming vehicle on the main freeway be informed of this early enough to allow it to slow down so that it doesn't smash into it?

The cheapest and easiest way is to simply note that the vehicle that has lost power has stopped communicating with the central computer and assume that it is no longer driving the wheels. This is not particularly good as we don't know if it is just some communications fault and the vehicle is still able to go at full speed. Consequently we really need a method of identifying position of each vehicle that is independent of the vehicle having power.

Possible methods are as follows:

- Utilise contactless smart card technology. The integrated circuits designed for this technology are embedded into the outer surface of the vehicle. This method has an advantage in that the card can provide more information such as specifying the particular vehicle, specifying which card, front, middle or back of the vehicle etc along with error checks.
- Sets of permanent magnets are placed on the vehicle where they can be read by system sensors. Placing multiple sets of magnets in each vehicle, such as one in the front, one in the back and one in the middle will reduce the number of system sensors needed. The magnets

could be placed on the side of the vehicle just below the body of the vehicle. These magnets can be measured by a number of cheap and easy methods such as Flux-gate magnetometer sensors, Hall effect magnetometers, Magneto-resistive devices or inductive pick coils.

- Sets of objects with specific magnetic properties (typically metals with specific compositions) are placed on the vehicle where they can be read by system sensors. The objects are read by what is effectively miniature metal detectors. These could be single coil or double coil sensors but at least one of the coils has to be energized. Energization of the coil could be by continuous AC frequencies or by pulses. The received signal can provide both distance to the objects (by amplitude of the received signal) and an indication of composition/magnetic properties of the objects (by phase of the received signal). This may have problems with interference with the metal bodies of the vehicles. This is particularly so as the system will have different types of vehicles, most of which have a metal body with different compositions of metal and difference configurations.
- Some visible tags such as barcodes are placed on the vehicle and these are read by system sensors as they pass by. This method has an advantage in that the barcode can provide more information such as specifying the particular vehicle, specifying which tag, front, middle back etc along with error checks. As well as the barcode we could have begin and end lines at the beginning and end of the tag and by measuring the time taken for these to pass a sensor we can have an accurate measure of the vehicles speed.
- While such optical methods are cheap and accurate, these optical methods have problems with dust, snow and ice, insects, buildup of dirt, repositioning after bumps etc. If continuous maintenance is done, the likelihood that these were not working when needed is infinitesimally small. Note, that at any time any vehicle or any specific tag on a vehicle goes past a sensor and that tag is not correctly recognized, that information should be available to the system and the system should be able to get the vehicle or system sensor fixed. Utilizing this with continuous maintenance combined with multiple sensors and multiple tags per vehicle should produce a very reliable system.

G) Other

(To be investigated further)
Other sensors will be needed to be able to sense if the car is performing correctly. In particular, there needs to be sensers for the following:

- tyre punctures, blowouts etc
- electric motor vibrations/excess noise etc
- other signs that maintenance is needed.
- battery charge
- doors open/shut
- smoke/fire alarm
- acceleration (G meter)

Dangers/Problems to Implementing this type of Transport System:

- Creates unemployment (or appears to).

  Business needs good transportation. Consequently, the overall effect of a better transportation network is likely to be an increase in business and consequently an increase in jobs. Unfortunately, many of the jobs lost as part of this process are more obviously associated with the creation of the new transportation network.
- Major threat to profits of large corporations such as the gas industry, automotive insurance and car manufacturing.
- IP Intellectual Property problems:

  Creation of patents for what is essentially obvious to those with a good technical knowledge. The current low historical usage of the concepts along with the complexity of a full network and the range of types of implementation, many of which have not been implemented, means that there is a large range of likely designs that may end up being optimal for specific situations. Any person or corporation with a good knowledge of current and upcoming technology trends can easily match those trends with requirements of implementation to create patents which in reality do little to advance our knowledge but rather tie up and act as a deterrence to proper research. As a possible example of this it should be noted that in 2004 the US granted a patent for the concept of adding solar and/or wind power collection into PRT network infrastructure (U.S. Patent 6,810,817).

  Note: One of the objectives in the creation of this document is to publish a substantial proportion of the concepts likely to be used in implementing a High Capacity PRT/podcar network so that these concepts become public domain.
- Regulatory powers can produce excessive regulations that make this type of system prohibitive and can block full systems after they have been fully designed. This is particularly problematic as the technical experts who produce the regulations often see these systems as a threat to their career. That is, they don't want to be steam train experts when no one wants new steam trains.
- Regulatory requirements for disabled access. For example, more and more, fire departments and other emergency service providers are requiring elevated guideway systems, such as monorails, to be equipped with emergency evacuation walkways, wide enough for wheelchairs.
- Change in legal responsibility in case of accidents shifts responsibility for accidents from the drivers to the transportation system.

Examples of PRT Concepts Being Non Optimal

While the 'Demonstration Analysis of PRT's Advantages' section in the Introduction should have demonstrated that PRT principles will generally take a transport system towards optimal, it should be noted that it does not do so in all circumstances. For example, if a route such as an airport to city link had only two substations, analysing the optimal in that circumstance would produce the result that the larger the vehicle or train that could be filled up, by waiting the most time allowed, would produce the most optimal.

PRT only becomes optimal when there are a significant number of stations and its advantages increase with very large numbers of stations.

PRT assumes typical traffic pattern. These typical patterns show that there is an average of 1.2 people in each vehicle on freeway/expressways or other highway roads. This result has been repeated in many countries.

An example where this pattern was quite different was the first implementation that was roughly of this PRT type. This was the implementation in Morgantown [16]. This town is a University town with Campuses in different locations. In this situation, students finish their lectures at the same time such that groups of people all need to move to either another campus or to their accommodation at the same time.

In this case optimising required a larger size so it was implemented as a Group Rapid Transit (GRT). GRT is like PRT except that the vehicles can be designed for up to 25 people. The highly successful Morgantown PRT [16] (it was called PRT by the implementers) can be classed as an Optimised Rapid Transport (ORT) that met the needs of the town of Morgantown but it doesn't meet the full requirements of High Capacity needed for handling the traffic of large cities. This has yet to be implemented.

Morgantown PRT vehicle on guideway

It should also be pointed out that taking extreme views on each concept does not necessarily produce the most optimal result. For example, always sticking to the PRT requirement that 'all trips should be just direct origin-to-destination with no need to stop at intermediate points'.   Breaking this rule, along with breaking the 'for exclusive use of an individual or small group travelling together by choice' rule can be used to increase efficiency.

Examine what happens if instead of the first passenger going direct to their destination, our passenger pickup strategy allows another passenger to share the vehicle, with the second passenger going to an intermediate substation on the route of the first passenger. It is fairly clear in this instance that the total energy of getting these two passengers to their destinations is less with them sharing than if they used different vehicles.

This appears to contradict the earlier findings. If the above principle of sharing was continued with multiple destinations on the route, and then expanded with larger vehicles to allow more sharing etc, we would end up with the original BRT or Light Rail systems which we showed was not optimal.

The above sharing of route arrangements only shift us towards optimal if kept to a small amount. Particularly, increasing vehicle size will take us away from optimal except very specific and rare cases.

Places Within Networks Where PRT Does Not Perform as Well as Competing Technologies:

- Compared to train stations, its ability per land area used to handle massive traffic after major events such as Football grand finals is not as good. Note that although beaten here by trains, it is able to handle these per land area used several times better than cars in car parks can handle it
- Seat utilisation in peak periods is poor in comparison to other public transport methods. This can be mitigated to some degree by the strategies suggested in this document for peak periods.
- Subway substations (metro) in centres of major CBDs may be more costly per user than for train stations as it can take more area with sidings etc to handle a large amount of traffic. In general, PRT systems works better and are more economical when elevated than going underground. With current train subway stations, the subway track normally acts as the main thoroughfare. If subways were required, the better design for PRT is to make the subway line a siding, with the thoroughfares outside the tunnel. Problems with using PRT for a subway mainly occur when an already finished subway designed for trains is allocated to be used for PRT.
- Earthquake resilience is not as good as roads but probably equal to or better than that of rail.
- PRT has a lot of unknowns and consequence risk. The 'Sydney Opera House Design Problem' is that we cannot reliably provide estimates of cost or time to implement something that is very different to anything previously built. When things are sufficiently different, they generally end up costing several times the cost of anything that could be estimated at the beginning. The problem worsens when attempts are made to take this into account. Each person, group or section involved in the design or implementation expands their resource uses to use up the extra allocated. When problems ultimately surface, the extra resources allocated have already been used.

The HCORT variant of PRT described herein adds the following problems:

- Pneumatic tyres are subject to punctures and blow outs
- Pneumatic tyres have a significant negative impact on the environment
- Flooding. The Near Grade design introduces a lot of underpasses where it will be critical to ensure that water is removed.

Possible Places where costs could blow out:

- Fences/separation of people from vehicles
- Elevated guideways
- Elevated substations
- Mechanical/hydraulic backup of steering systems based on running tracks
- Water removal from trenches
- Inter-vehicle latch

- Supply rails/catenary wires, collectors, trolley poles,
- Capacitive/ultracapacitor charging
- Near grade overpasses

Concepts where this new HCORT system is not in accordance to earlier PRT Concepts:

- Some places on the network are not fully fenced from pedestrians, particularly side lanes.
- Ordinary non automatic road vehicles can travel on side lanes used by HCORT vehicles.
- Suggested substation passenger pickup strategy for peak traffic

Problems related to methods that optimise vehicle seat utilisation:

- "Rape Wagon!" This is discussed in the next section.
- Having to share a vehicle with someone who smells.
- Having to share a vehicle with someone intoxicated.
- Having to share a vehicle with someone who is noisy while you want to rest or talk to someone on the phone.
- Having someone next to you that wants to talk to you when you don't want to talk to them.

Rape Wagon:

In the 1970s and early 1980s there was a major (and expensive) attempt at designing a PRT system with money from the French Government. The PRT system (Aramis) had a similar seat optimisation to that being suggested in this document. The government money being put into this PRT system was at times controversial with the following being said in their parliament:

> " Senator Wallace: "If I may say so, there's something else that hasn't been perfected in this business. What if instead of finding her 'cronies,' as you put it, in this closed car with no driver, your housewife runs into a couple of thugs? (I didn't say 'blacks '-be sure to get that straight.)
>
> Then what does she do? What happens to her then?"
>
> Jim Johnson (at a loss for words): " Uh . . . "
>
> Senator Wallace: " Well, I'll tell you what happens, she gets raped!

> And the rapist has all the time in the world, in this automated shell of yours with no doors and no windows. You know what you've invented? You've invented the rape wagon!"
>
> [Shouting, commotion]"

Since the 1970s technology has made major strides with the costs of audio visual equipment being orders of magnitude cheaper and better. It is now no longer a problem to have multiple cameras and microphones in each vehicle along with continuous transmission to a central control and continuous recording of the audio visual data.

It is now also relatively easy and cheap to have these video and audio streams monitored by computers so that people don't have to watch it all. Computers may not yet be able to recognise all actions that happen in the way that people can but they can recognise certain warning signs and suggest certain audio video for the central control people to monitor. For example, it is easy for computers to recognise that an attempt is being made to cover over the cameras. Voice recognition may not yet pick up all words of all people but the combination of voice recognition along with tones and/or pitch or similar that suggest a cry for help etc should not be that hard for computers to recognise and take appropriate actions.

Central controller people will have the ability to talk to people in vehicles, letting them know that they are being monitored and persuading them not to do particular actions. Central Controller people will have the ability to re-route vehicles including being able to route a vehicle to a police station with the doors locked. This makes all HCORT passenger vehicles potential paddy wagons rather than rape wagons.

The sharing arrangements suggested only occur in peak periods. Peak periods are mainly daylight hours and the above attempts at rape or similar are more likely to occur late at night.

Any person is able to have their own vehicle in peak periods. They just have to pay more. People with special requirements should not have to pay extra.

The ability to have the new transport system drive passengers right to or from their property provides far greater safety than that obtained from other public transport systems. The problem with this, at least in the early implementions, is that only a subset of passengers will have this capability. Many of the users will be people who live in a street near to a substation but since the system isn't in their street, they initially will only access it by walking to and from the substation. When ultimately, full autonomous vehicles are road safe and integrated into the system, they will have other options.

Appendix A: Official Positions on PRT

Regardless of earlier expensive implementation failures, along with the controversy on the concepts, there has recently been major research studies by, or on behalf of, the transport authorities of both the USA and Europe. As a consequence of these studies, it can be stated that the position of transport authorities in both USA and Europe is that we should be directing research towards implementing PRT/ATN/podcars.

Details on the findings of these studies, including a description of the main ATN/PRT/podcar concepts, is included below

USA's Official Position:

Mineta Transportation Institute (MTI) was originally established by Congress and is funded by Congress, California and private grants.

What has traditionally been called PRT, they call ATN. Their report published September 2015 provides the following:

> "ATN – sometimes referred to as personal rapid transit (PRT) or Podcars – is a unique transportation mode that features:
>
> - Direct origin-to-destination service with no need to transfer or stop at intermediate stations
> - Small vehicles available for the exclusive use of an individual or small group traveling together by choice
> - Service available on demand by the user rather than on fixed schedules
> - Fully automated vehicles (no human drivers) that can be available for use 24 hours a day, 7 days a week
> - Vehicles captive to a guideway that is reserved for their exclusive use
> - Small guideways (narrow and light relative to light rail transit or LRT and bus rapid transit or BRT) that are usually elevated but that also can be at or near ground level or underground
> - Vehicles able to use all guideways and stations on a fully connected network
>
> The scope of the study excludes what is called, 'dual mode transit', where vehicles are allowed to enter and exit the guideway."

The study concluded that " ATN appears to have potential" ... but "More research, development, and validation are needed" ... and that they should "Sponsor research" ...
including "Incentivize metropolitan planning organizations (MPOs) to develop concepts using ATN to further sustainable transportation by issuing a request for proposals (RFP) for ideas." etc.

Europe's Official Position:

The EDICT project [2], sponsored by the European Union, conducted a study on the feasibility of PRT. The study involved 12 research organizations, and concluded that PRT

- would provide future cities "a highly accessible, user-responsive, environmentally friendly transport system which offers a sustainable and economic solution."
- could "cover its operating costs, and provide a return which could pay for most, if not all, of its capital costs."
- would provide "a level of service which is superior to that available from conventional public transport."
- would be "well received by the public, both public transport and car users."

The report also concluded that, despite these advantages, public authorities will not commit to building PRT because of the risks associated with being the first public implementation!!!

Appendix B: Size Matters

Scaling designs of some things produce the result that the larger the better. For example, the larger the office building the more space one obtains per cost of building and per unit of land. Similarly, the power obtained from a jet engine goes up more than the square of the cost of the jet engine.

People sometimes get used to this and expect it to continue to all things, but there are some major examples where scaling works the opposite way.

Computer Scaling Effects:

Grosch's law or Seymour Cray rule (postulated in the 1940's) postulated that:

cost of computer systems increase with the square root of their power

By the mid 1950s enough computers had been built to verify the law empirically and for a while Grosch's law worked well. Then minicomputers, microcomputers and the personal computer came along and the law fell apart. Now, small computers often have a price per performance ratio 100 times better than large computers. This is the opposite to what the above law predicts.

The above is lucky for HCORT design as it will use large numbers of small computers.

Vehicle Scaling Effects:

The costs this author has [10] are those locally in Australian dollars. An Australian dollar is roughly worth about US$0.75 at current exchange rates.

From a $600 million purchase, cost of a local train was $16m/train
(Note: limited to 90 km/h (56 mph) due to technical issues)

$32,000 per seated passenger (at 500/train)
$20,000 per passenger standing or sitting (at 800/train - a full train)
$14,000 per passenger standing or sitting (at 1100/train - a ridiculous crush/squash)

Light Rail/Trams (streetcars) had a price of $272m for 50 trams, or about $5.5m per tram.

$85,000 per seated passenger (at 64/tram)
$25,000 per passenger standing or sitting (at 214/tram)

This needs to be compared with cars. Recently this author has hired small cars with 'unlimited kilometres per day'. These cars were allowed to be driven out in the country including various rough roads, so they had many advantages compared to trains and light rail which are very restricted. These small cars provided 5 seats each. If these small cars were purchased by the hire company in the above multi million dollar purchases, the cost would be well below $10,000 per vehicle and consequently less than $2000 per seated passenger.

The ratio of cost for rail vehicle per cost of seat for a car is staggering. Even cost of vehicle for a person standing on a light rail vehicle is over 12 times the cost of a seat for a small car.

Buses are approx $250,000 for a 50 seat bus. Note: I don't yet have good figures on this. This is $5,000 per seat but cost goes up above this as the bus gets bigger & can be lower than this with mini buses.

In general costs per seat go up with size of vehicle rather than the opposite way but there are major variations to this with the smaller light rail being more expensive per seat than trains.

Overall, numbers of vehicles being made in the world determines technological advancement of the vehicle type and consequently cost per seat. Consequently buses are far cheaper than light rail, even when they are the same size.

The above may be objected to in that the expensive vehicles will last longer than the cheaper ones. This is more that, due to the cost we are required to carry on using and maintaining the expensive vehicles than that they naturally last that long. We naturally replace cheaper vehicles earlier because it is cheap to do so. Cheap cars are now being given five year unlimited kilometre warranties that trains and light rail don't get.

Appendix C: Automated vs Autonomous

These HCORT vehicles are not "Autonomous" with the current usage of this word. Rather they are automatic and driverless. Autonomous control implies good performance under significant uncertainties in the environment for extended periods of time and the ability to compensate for system failures without external intervention.

In transportation terminology, rather than autonomous, PRT is a subset of Automated Guideway Transit (AGT) [20]. Automated guideway transit is a fully automated, driverless, grade-separated transit system in which vehicles are automatically guided along a "guideway".

The HCORT design has some characteristics that are similar to the concept of fully autonomous vehicles such as the Google car. It's similar in that we're talking driverless automated vehicles based on standard vehicles with rubber tyres (probably pneumatic) that are able to drive on a flat roadway. Also, both allow privately owned vehicles to use them as well as being able to be used for public transport.

Comparative Advantages of Fully Autonomous Vehicles

- Massive amounts of R&D money has been available from the military. Historically, this is the main reason they got developed as quickly as they did.
- No modification needed to the roadways etc
- Will not cause massive loss of jobs to car industry or massive negative effect to other industries such as insurance, oil & gas, road building etc
- Extended reach of automated vehicles (i.e. able to go out to farms etc)
- Larger vehicles such as trucks able to take advantage of it.

Comparative Advantages of PRT

- Massive decrease in time taken for trips.
- Massive decrease in energy used.
- Massive decrease in global warming gases, noise, pollution etc.
- Massive decrease in accidents and road deaths.
- Substantially fixes street congestion problems.
- Substantially fixes parking problems.
- Vehicles (private & public) recharged on journey.
- Is technically far easier.
- Potentially far cheaper.

The first six of the above items are touted by autonomous vehicle proponents as reasons to have autonomous, and yes, autonomous may help these, but compared to PRT, only in a trivial way.

Major reasons PRT is able to give these:

- Dedicated system (eg pedestrians don't walk across etc).
- Freeway/expressway guideways (Lack of stopping at stop lights etc.)
- Higher speed on dedicated guideway with all vehicles being under the same computer control.
- Safer on dedicated guideway with all vehicles being under the same computer control.
- More people converting to shared public transport.
- Conversion to electric motors.

Attempting to get some of the PRT advantages to Autonomous Vehicles

Minimum Requirements:

- - All vehicles converted to new autonomous system and
- - Additional central computer used for control and
- - Most streets converted to one way traffic.

Then a significant proportion of PRT advantages could be obtained but we've lost the fully autonomous. Interestingly, the type of central computer control required here would make the system less autonomous than many PRT designs.

There's not a lot of advantage to vehicles in the early stages so getting all vehicles to convert would be very difficult. To overcome this is going to require that streets allocate specific lanes to the autonomous traffic.

Continuing with changes to try to get more of the PRT advantages such as changing the dedicated streets into freeways/expressways basically continues to change the autonomous system into this HCORT system.

In many aspects of current autonomous research, the designs are heading to being less autonomous to overcome their limitations. For example to advance Adaptive Cruise Control, research is heading towards Cooperative Adaptive Cruise Control (CACC) [17].

The odd thing is that our technology is currently able to make safe HCORT transport systems across our cities (due to the reserved and dedicated guideways) but is not yet able to make safe autonomous systems (due to the 'uncertainties' requirement).

References:

1: MTI report published September 2015 entitled:
Automated Transit Networks (ATN): A Review of the State of the Industry and Prospects for the Future
http://transweb.sjsu.edu/PDFs/research/1227-automated-transit-networks.pdf

2: EDICT Final Report (PDF) from cardiff.gov.uk
http://archive.cardiff.gov.uk/traffic/internet/jondutton/edict/current/CONTENT/Del10%20-%20Final%20Report.pdf

10: From 2011 Auditor-General's report into the state's finances (page 38) we have cost of trains and light rail/trams in Melbourne, Australia:
http://www.audit.vic.gov.au/publications/20111109-AFR/20111109-AFR.pdf

Wikipedia References:

11: PRT
https://en.wikipedia.org/wiki/Personal_rapid_transit

12: Multilateration
https://en.wikipedia.org/wiki/Multilateration

13: Dedicated short-range communications (DSRC)
https://en.wikipedia.org/wiki/Dedicated_short-range_communications

14: IEEE 802.11p. A special version of Wi-Fi
https://en.wikipedia.org/wiki/IEEE_802.11p

15: V2V (short for vehicle to vehicle)
https://en.wikipedia.org/wiki/Vehicular_communication_systems

16: Morgantown PRT
https://en.wikipedia.org/wiki/Morgantown_Personal_Rapid_Transit

17:Cooperative Adaptive Cruise Control (CACC)
https://en.wikipedia.org/wiki/Cooperative_Adaptive_Cruise_Control

18: Height Adjustable Suspension
https://en.wikipedia.org/wiki/Height_adjustable_suspension

20: Automated Guideway Transit (AGT)
https://en.wikipedia.org/wiki/Automated_guideway_transit